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WINTERTIME 1974-75 WESTERN GULF OF MAINE EXPERIMENT DATA REPORT

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W. S. Brown, J. A. Vermersch, and R. C. Beardsley

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TECHNICAL REPORT

Prepared for the National Science Foundation under Grants DES 75-03992 (UNH), DES 74-03001 (MIT), and OCE 76-01813 (WHOI).

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Approved for Distribution ______________________
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Abstract

Summaries are presented of basic hydrographic measurements and current, temperature and pressure measurements which were made from moored instruments as a part of the Wintertime 1974-75 Gulf of Maine Experiment which took place November 1974 to January 1975.

WINTERTIME 1974-75 WESTERN GULF OF MAINE EXPERIMENT DATA REPORT

I. Introduction

The principal goal of this experiment was to determine the effect of the passage of wintertime storms on the general circulation in the Western Gulf of Maine. One element of the field program consisted of a moored current meter, temperature, and bottom pressure array which is shown in Figure 1, and the other was a hydrographic program.

The current meter moorings were deployed with subsurface floats and Wunsch/Dahlen bottom pressure sensors were mounted on satellite anchors attached to the main current meter mooring anchors. The details of the moored array appear in Table 1 while a discussion of this array appears in Part III of this data report. During the experiment, 10 hydrographic cruises were interleaved with the storms which pass through the region. The principal transects of that survey are indicated in Figure 1 and a chronology of events is shown in Figure 2.

A number of auxiliary data sets were obtained and are to be used to assist in the interpretation of the primary results of the experiment. These data include National Ocean Survey (NOS) coastal sea level records, six hourly meteorological maps of the area, and air-sea interaction parameters which were measured aboard the Portland Lightship.

Table I: SUMMARY OF WESTERN GULF OF MAINE MOORED ARRAY

Mooring	Data ID	Depth m	Instrument	Current	Temperature	Pressure
1 - Monhegan	11	33	VACM	x	x	
43° 40.3' N	12	68	102-cm	x		
69° 22.7' W	13	98	T/P recorder		x	x
2 - Cashes Ledge	21	33	VACM	x	x	
43° 10.9' N	22	68	102-cm	x		
69° 05.0' W	23	118	102-cm	x		
	24	190	T/P recorder		x	x
3 - Cape Porpoise	31	33	VACM	x	x	
43° 12.9' N	32	68	102-cm	instrument failed at launch		
69° 16.6' W	33	98	T/P recorder		x	x

Instrument Sampling Modes:

VACM — currents: 15 minute vector averages
temperature: one sample every 15 minutes

102-cm — currents: 12 strobe burst of direction every 10 min with 5 sec between strobes, and with speed averaged over burst duration

T/P Recorder — pressure: 7-1/2 min averages
temperature: 7-1/2 min averages

II. Hydrography

A. Objectives

The principal goal of the hydrography program was to document the wintertime evolution of the temperature, salinity, and density fields in the region of the moored array. Estimates of geostrophic shear to be calculated from these measurements can be compared with current meter results.

B. Data Acquisition

The elements of that hydrographic program included vertical temperature profiles, surface temperature, surface salinity, and deep salinity samples. Table 2 summarizes these measurements.

A composite set of these measurements were made during a typical one-day R/V Gulfstream cruise, which consisted of one offshore and one onshore section. Section A, which lies between the Monhegan and Cashes Ledge moorings (moorings 1 and 2, respectively) was occupied during all Gulfstream cruises, while Sections B, C, and D (Figure 1) were occupied less regularly. Underway surface temperatures were recorded every ten min (∿4.5 km), while surface salinity and XBT stations were made every 20 min (∿9 km). During many but not all of the cruises hydrographic stations were made at about 20 km separations.

(1) Surface Salinities and Temperatures

A continuous flow of water was pumped aboard the R/V Gulfstream through the underside of the hull from an approximate depth of 1 meter. Surface salinity samples were drawn periodically from the exit hose. The salinity of these samples was determined from the conductivity ratio measured by a Guildline Auto Sal Salinometer Model 8400, whose precision is better than an equivalent ±.001 ‰.

NUMBER OF STATIONS

CRUISE		DATE	XBT	NANSEN SALINITY	SURFACE SALINITY	SURFACE TEMPERATURES
(1)	5	29 Nov 1974	25	-	25	66
(2)	6	5 Dec 1974	23	4	37	72
(3)	7	6 Dec 1974	26	3	29	69
(4)	8	11 Dec 1974	32	-	39	92
(5)	9	18 Dec 1974	5	1	11	35
(6)	10	20 Dec 1974	28	4	36	99
(7)	12	29 Dec 1974	36	6	37	70
(8)	13	31 Dec 1974	-	-	28	62
(9)	14	3 Jan 1975	35	6	37	74
(10)	15*	15 Jan 1975	-	-	27	27
(11)	16*	16 Jan 1975	-	-	16	16
		TOTALS	210	23	322	682

Table 2: Summary of hydrographic measurements. With the exception of cruises 15 and 16 which were made on the USCG SPAR (*), all cruises were made on the R/V Gulfstream.

Temperatures were measured in an onboard manifold in two ways. A thermistor temperature was measured and recorded continuously on a strip chart recorder, while quartz crystal temperatures* were recorded at discrete intervals while underway and at XBT stations. The thermistor record was used to identify regions of large horizontal temperature gradient and thus assist in the interpretation of the discrete quartz temperatures. Tests of the onboard temperature measurement system showed (i) a temperature measurement lag of 9 sec (equivalent to about 100 m horizontal displacement at 17 kts), and (ii) that typical onboard temperature differences were less than .03° C.

(2) Expendable Bathythermograph (XBT)

The greatest emphasis was placed in the XBT program. A number of different model Sippican Inc. XBT's (T4, T6, T7, T9, T10) were launched from the R/V Gulfstream while underway at about 17 knots. Surface temperatures and salinities were obtained simultaneously with each cast. The XBT traces were digitized using a Wayne-George, Inc., X-Y Digitizer at nominal intervals of 5 meters with denser rates in regions of large vertical gradient.

The manufacturer's specifications for temperature accuracy of ±.2° C were improved by correcting the "surface" XBT temperature with the quartz thermometer "surface" temperature. The actual depths of these measurements were about 4 m and 1 m respectively. During most seasons this type of correction is not justified. However, for these wintertime measurements, the majority of the XBT traces clearly show an isothermal surface layer to a depth of at least 10 m. A comparison of quartz and XBT "surface temperatures," such as the example shown in Figure 3, suggests that (i) the manufacturers

*Measured with a Dymec quartz crystal temperature sensor model 2850 C; Hewlett Packard, Inc.

indicated accuracy is realistic, and (ii) differences in surface temperature depend more upon thermistor characteristics than on vertical temperature gradients in the upper 5 m of the water column. It was concluded that adjusting the surface XBT temperature to that of the quartz temperature reduces accuracy errors to an estimated ±.05° C.

(3) Hydrographic Casts

Deep salinity samples were obtained with several hydrocasts using standard Nansen bottles at nominal depths of 0, 20, 60, and 100 m during each cruise. These salinities were processed in the same manner as the surface salinities. At each hydrostation, surface salinity samples were obtained, surface temperatures were recorded, and an XBT was launched.

(4) Density Field

Sigma-t (σ_t) values were calculated using Knudsen's relations (LaFond, 1951) where possible. This was done for surface salinity and quartz temperature pairs and deep corrected XBT temperature and salinity pairs. Based on the estimated uncertainties of temperature and salinity values of ±.05° C and ±.001‰ respectively, the estimated uncertainty in σ_t is ±.015.

(5) Navigation

An Epsco Loran-C was used routinely as the primary navigation device. The precision of the Loran position was enhanced by adjusting positions according to time during uninterrupted cruising of 1 hour or more, assuming an average cruising speed. Thus relative precision of the indicated station positions is estimated to be about ±.1' in latitude and ±.2' in longitude.

C. Hydrographic Data Presentation

Surface and vertical sections of temperature, salinity, and density are presented. Isopleths of surface temperatures, salinities, and density are shown with the appropriate cruise track in Figures 4 through 19. Isopleth contour intervals of .5° C, .2 ‰, and .2 in sigma-t are mutually consistent and much larger than the estimated uncertainties. The results from cruises 6 and 7, 12 and 13, 15 and 16 were obtained within two days of each other and are combined for presentation purposes.

(1) Surface Sections

The combined surface data represent a description of the wintertime evolution of the Western Gulf of Maine temperature, salinity, and density fields. The temperature sequence (Figures 4, 6, 8, 10, 12, 14, 16, and 18b) is characterized by a convergent surface front which represents a mixing zone between the colder and fresher outflow from the Kenebeck River and coastal Gulf of Maine water. The 7° C isotherm, which is representative of the front, appears to "meander" about the 100 m isobath. It is not clear what aspects of the movement are due to advection and/or mixing. In contrast, the offshore water exhibits "patchiness" which gradually disappears during December as the water in the study area cools from about 8.75° C to about 7.75° C. The salinity sequence (Figures 5, 7, 9, 11, 13, 15, 17, and 19c) is characterized by the apparent movement of a surface front and a decrease in the offshore salinity gradients during the month of December. The effects of the Penobscot River which outflows "up coast" are probably indicated by the offshore direction of the 33.4‰ isohaline. Both the evolution of the front and the decrease of offshore gradients are indicated in the density sequence (Figures 5, 7, 9, 11, 13, 15, 17, and 19d). Density patchiness, which can be observed in early December, is very suggestive of the surface expression of downwelling features which were observed in the Mediterranean during MEDOC (1970). The general increase of density, which is observed to occur in December, can be attributed to the decrease in temperature of the water since the effects due to salinity changes are small.

(2) Vertical Sections of T, S, and σ_t

The depth variability of temperature, salinity and density are summarized in the offshore and onshore sections shown in Figures 20 through 30. The same contour intervals which were used for the surface section are used here, i.e., .5° C, .2 ‰, and .2 for sigma-t. Clearly the corrected XBT temperature field is best resolved from the vertical digitization interval of 5 meters at all the indicated stations. Much coarser estimates of the salinity field and therefore the sigma-t field are obtained from the hydrostation data. With notable exceptions in the deeper basin areas, measurements do show that to the selected precision, the salinity field is more well-mixed than the temperature field. Many of the detailed features of the sigma-t field have been inferred from a combination of this observation regarding salinity distribution and the temperature distribution. No deep salinities were obtained for cruises 5 and 8, thus only the temperature sections are presented. No XBT temperatures or deep salinities were obtained during cruise 13.

A representative example of the early winter deep structure in the T, S, and σ_t fields (as determined from measurements made on 6 December along track C) is shown in Figure 22. One of the prominent features is the frontal structure, which appears here to be confined to depths less than 50 m. This presentation shows that the "patchiness" is just an expression of temperature-induced overturning which appears to mix the full water column to a local depth of about 150 m. At station 6 the density decreases from σ_t = 26.00 at the surface to 25.92 at the bottom, an unstable condition which is found near the surface at this station and elsewhere. The colder bottom water may be remnant water from the previous cooling episode.

An example of midwinter deep structure in the T, S, and σ_t fields (as determined from measurements made on 3 January 1974 along section B) is shown in Figure 29. Evidence of the front has disappeared and a greater portion of the water column is fully mixed due to the same convective processes which were observed in early December.

(3) T-S Relations

The hydrographic data from the experiment is summarized in the T-S diagrams which appear in Figures 31 through 34. Although most profiles show reasonable vertical stability, there are examples from most cruises which are clearly unstable (e.g., 7/6 and 6/45 in Figure 31). Figure 35 summarizes the seasonal variability in the typical T-S relations of Gulf of Maine water and continental slope water and places the 1974-1975 data in perspective with historical data. The other T-S curves summarize the Gulf of Maine measurements of Colton et al. (1968) which were obtained during a series of cruises aboard the R/V Albatross during 1964-65. The upper water ($Z < 100$ m) characteristics are strongly influenced by the seasonal changes in the surface heat transfer processes, local runoff, and perhaps influx of Scotian shelf water. The composition of the deepest water ($Z > 200$) is influenced principally by the intrusion of continental slope water through the Northeast Channel. Of particular interest here is the water mass at depths between 100 and 200 m which is associated with the December temperature minimum. Apparently this water mass, which will be referred to as Gulf of Maine intermediate water (MIW), is a remnant of water formed during the previous winter. MIW is the likely source of "COOL POOL WATER" which has been observed in temperature sections across the continental shelf by Beardsley and Flagg (1976) and others on the New England Shelf, and Boicourt and Hacker (1976) as far south as Maryland.

III. The Moored Array

The moored array component of the experiment was designed to document the forced current and sea level response to several strong meteorological events. The complex topography, large size and semi-enclosed nature of the Gulf of Maine made design of a sensible experiment difficult. We felt, however, that an exploratory "event" study should be made and understood before any large-scale, extensive general circulation experiment could be properly designed. We view this work as a "pilot" study which hopefully will suggest strategies for future experiments.

A. Design

The array consisted of three sub-surface moorings, each of which contained at least two current meters and one bottom-mounted pressure/temperature recorder. Figure 16 and Table 1 summarize the mooring locations, instrument depths, and sampling characteristics. The array was deployed between November 1974 and January 1975.

The alongshore element (moorings 1 and 3) of the array was located near the 100 meter isobath (Fig. 1). On each of these moorings an AMF vector-averaging current meter (VACM) was set at 33 meters, and an EG&G 102 film current meter (FCM) was set at 68 meters depth. Mooring 2 was located about 40 nautical miles offshore in about 190 meters of water, and had a VACM at 33 meters, and FCMs at 68 and 118 meter depths. The placement of mooring 2 was designed to give additional information on the offshore structure of the alongshore flow plus an indication of any induced deep currents. The 102 current meters had been fitted with electronic clocks to improve their time base generation.

A Wunsch-Dahlen pressure/temperature recorder (Wunsch and Dahlen, 1974) was deployed on a separate bottom anchor at each mooring site. The satellite anchor holding the pressure/temperature recorder was attached to the current meter mooring by a long ground line, thereby isolating the pressure-measuring instrument from any mooring motion.

B. Data Presentation

The data obtained from the moored array is presented in three sections: Currents, Moored Temperatures, and Pressure.

(1) Currents

Each current meter data record is labeled as WGMij, where WGM stands for Western Gulf of Maine, i is the mooring number, and j is the instrument sequence number, starting at the top of each mooring. For the instrument at 33 meters depth, j = 1 and for the 68 meter depth instruments, j = 2. The only case of j = 3 occurs for the deepest current meter on mooring 2 at 118 meters. The designation A1H at the end of the label indicates that one-hour averages were made of the raw data, A1D indicates that daily-averaged data are displayed, G24 indicates that hourly-averaged data were low-pass filtered by applying a running Gaussian filter with half-power width of 24 hours, and PL33 indicates that the hourly averaged data were low-pass filtered by applying a running polynomial/linear filter (Flagg, Vermersch, and Beardsley, 1976).

The data for each instrument is presented as a unit consisting of four figures. The first figure of each unit displays the progressive vector diagram for the daily-averaged data along with an East and North correlation (SCATTER) plot of the hourly-averaged data. The second figure of each group displays the statistics and spectra computed on the hourly-averaged data. The statistics and spectral calculations were based on common start and stop times for all the instrument records, encompassing 1361 data cycles; however, the time series were extended with zeroes to become 1440 points for the spectral calculations. The spectra are shown in two formats: (1) as the log of the energy density versus the log of the frequency, and (2) as the frequency times the energy density versus the log of the frequency (the variance conserving form). Figure 36 displays the ninety percent confidence interval for the logarithmically band-averaged spectra. The third and fourth figures of each instrument group display the hourly-averaged time series data, consisting of East and North components, speed and direction. The two time series figures split the data into approximately the first and second halves of the instrument deployment period.

Following the individual instrument records, Figures 61 and 62 display all six instrument records simultaneously as vector time series (North is up). The vector time series were computed after applying a running Gaussian filter to the hourly-averaged data, and then plotting every sixth point. The Gaussian filter has a half-power time width of 24 hours.

(2) Moored Temperatures

The moored temperatures are shown in Figure 63. This is a plot of the hourly averaged data from each mooring, with the VACM temperatures at 33 m depth being displayed above the temperature records from the bottom-mounted T/P recorders.

(3) Pressures

All of the pressure data obtained during the experiment is shown in Figure 64. The figure includes the sub-surface pressure (SSP) at several coastal stations as well as the bottom pressures from the moored array. The SSP was computed by adding the atmospheric pressure to the sea level records at each coastal station. All of the pressure time series have had the PL33 filter applied.

Finally, Figure 65 displays all of the current data along with pressure records from Portland and from mooring 3. The Portland records include atmospheric pressure, sea level, and the computed SSP. All of the time series shown in Figure 65 have been low-passed with the PL33 filter.

IV Acknowledgements

This experiment was made possible by the support and assistance of a number of individuals and groups. The foremost supporter of this work was Dr. William Richardson, who along with the crew of the R/V GULF STREAM were lost along with the ship on 4 January 1975. This tragedy marked a great loss to those of us involved in this experiment and the entire oceanographic community in general. Dr. Charles Yentsch, Director of the Bigelow Laboratory, kindly provided support for the hydrographic work. We would like to express gratitude to the U. S. Coast Guard for their support in terms of ship time and assistance in mooring development and recovery from the USCGC SPAR under Capt. (Cmdr.) J. Midgett. The credit for preparation and preliminary data handling from the pressure temperature gauges goes to John Dahlen's group at the C. S. Draper Laboratory. A special thanks goes to Dr. Carl Wunsch for the loan of those instruments. Other laboratories, including the Buoy Group at Woods Hole Oceanographic Institution and Nova University, loaned the current meters used in this experiment.

With regard to the hydrographic program, Mr. Jeffrey Thornton provided important assistance in acquiring and processing of the data. Mr. Fredrich Faller provided the local meteorological data. The crew of the PORTLAND LIGHTSHIP is to be thanked for supplying our special data request.

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VI Figure Captions

Figure 1. Location Map of the New England Continental Shelf.

Bottom pressure-temperature and current meter mooring sites for the 1974/75 Gulf of Maine Experiment (●). Four offshore hydrographic sections (••••••••) which were made at various times during the experiment are indicated. The bottom bathymetry is in meters. A schematic representation of the moored array appears in the inset.

Figure 2. A Chronology of Activities During the Gulf of Maine Experiment in the Winter of 1974/1975.

Figure 3. A comparison of quartz thermometer and XBT "surface temperatures" measured at a depth of 1 and 4 meters respectively. This representative example comes from a day of low surface cooling during which T9 (●), T10 (X), and T6 (o) XBTs were deployed. The manufacturer's uncertainty limits (±.2°C) are indicated by the dashed lines. These limits and the clustering suggests that thermistor characteristics are principally responsible for the scatter.

Figure 4 (a & b). The cruise track and surface temperature field respectively for Cruise 5; 29 November 1974. The bottom bathymetry is expressed in meters, the locations of XBT stations are indicated by (o); surface temperatures by (●); and the moored array by (▲).

Figure 5 (a & b). The surface salinity and density fields respectively for Cruise 5; 29 November 1974. The locations of surface salinity stations is indicated by (o), the surface density by (●), and the moored array by (▲).

Figure 6 (a & b). The combined cruise tracks and surface temperature field respectively for Cruises 6 and 7; 5 and 6 December 1974. The bottom bathymetry is expressed in meters, the locations of XBT stations are indicated by (o); hydrographic stations by (●); surface temperatures by (•); and the moored array by (▲).

Figure 7 (a & b). The combined surface salinity and density fields respectively for cruises 6 and 7; 5 and 6 December 1974. The locations of the surface salinity stations are indicated by (○); hydrographic stations by (⬤); surface densities by (●); and the moored array by (▲).

Figure 8 (a & b). The cruise track and the surface temperature field respectively for cruise 8; 11 December 1974. The bottom bathymetry is expressed in meters, the location of the XBT stations is indicated by (○); surface temperatures by (●); and the moored array by (▲).

Figure 9 (a & b). The surface salinity and density fields respectively for cruise 8; 11 December 1974. The locations of the surface salinity stations are indicated by (○); surface densities by (●); and the moored array by (▲).

Figure 10. The surface temperature field for cruise 9; 18 December 1974. The locations of the surface temperature stations are indicated by (●); hydrographic stations by (⬤); and the moored array by (▲).

Figure 11 (a & b). The surface salinity and density fields respectively for cruise 9; 18 December 1974. The locations of the surface salinity stations are indicated by (○); hydrographic stations by (⬤); and the moored array by (▲).

Figure 12 (a & b). The cruise track and surface temperature field respectively for cruise 10; 20 December 1974. The bottom bathymetry is expressed in meters, the location of the XBT stations is indicated by (○); surface salinity and temperature only by (◎); hydrographic stations (⬤); surface temperatures by (●); and the moored array by (▲).

Figure 13 (a & b). The surface salinity and density field respectively for cruise 10; 20 December 1974. The location of the surface salinity stations is indicated by (○); hydrographic stations by (⬤); surface densities by (●); and the moored array by (▲).

Figure 14 (a & b). The combined cruise track and surface temperature field respectively for cruises 12 and 13; 29 and 31 December 1974. The bottom bathymetry is expressed in meters, the locations of the XBT stations are indicated by (o); hydrographic stations (⬤); surface salinity and temperature only by (⊘); temperatures by (●); and the moored array by (▲).

Figure 15 (a & b). The combined surface salinity and density fields respectively for Cruises 12 and 13; 29 and 31 December 1974. The locations of the surface salinity stations are indicated by (o); hydrographic stations by (⬤); surface densities by (●); and the moored array by (▲).

Figure 16 (a & b). The cruise track and surface temperature field respectively for cruise 14; 3 January 1975. The bottom bathymetry is expressed in meters and the locations of the XBT stations are indicated by (o); hydrographic stations (⬤); surface temperatures by (●); and the moored array by (▲).

Figure 17 (a & b). The surface salinity and density fields respectively for Cruise 14; 3 January 1975. The locations of the surface salinity stations are indicated by (o); hydrographic stations by (⬤); surface densities by (●); and the moored array by (▲).

Figure 18 (a & b). The combined cruise track and surface temperature field respectively for Cruises 15 and 16; 15 and 16 January 1975. The bottom bathymetry is expressed in meters and the locations of the surface salinity stations is indicated by (o); surface temperatures by (●); and the moored array by (▲).

Figure 19 (a & b). The combined surface salinity and density fields respectively for cruises 15 and 16 respectively; 15 and 16 January 1975. The locations of the salinity stations are indicated by (o); surface densities by (●); and the moored array by (▲).

Figure 20. Track A and B temperature sections (above and below respectively), which were made during the offshore and inshore legs of cruise 5; 29 November 1974.

Figure 21. Track B temperature, salinity, and sigma-t sections which was made on the offshore leg of Cruise 6; 5 December 1974. The salinity (sigma-t) stations are indicated by (●).

Figure 22. Track C temperature, salinity, and sigma-t sections, which were made on the offshore leg of Cruise 7; 6 December 1974. The salinity (sigma-t) stations are indicated by (●).

F: ure 23. Track A and D temperature sections (above and below respectively) which were made on the inshore legs of Cruises 6 and 7; 5 and 6 December 1974 respectively.

Figure 24. Track A and C temperature sections (above and below respectively), which were made during the inshore and offshore legs of Cruise 8; 11 December 1974.

Figure 25. Track C temperature, salinity, and sigma-t sections, which were made during the offshore leg of Cruise 10; 20 December 1974. The salinity (sigma-t) stations are indicated by (●).

Figure 26. Track A temperature, salinity, and sigma-t sections, which were made during the onshore leg of Cruise 10; 20 December 1974. The salinity (sigma-t) stations are indicated by (●).

Figure 27. Track B temperature, salinity, and sigma-t sections, which were made during the offshore leg of cruise 12; 29 December 1974. The salinity (sigma-t) stations are indicated by (●).

Figure 28. Track A temperature, salinity and sigma-t sections, which were made during the inshore leg of Cruise 12; 29 December 1974. The salinity (sigma-t) stations are indicated by (●).

Figure 29. Track B temperature, salinity, and sigma-t sections, which were made during the offshore leg of Cruise 14; 3 January 1975. The salinity (sigma-t) stations are indicated by (●).

Figure 30. Track A temperature, salinity, and sigma-t sections, which were made during the inshore leg of Cruise 14; 3 January 1975. The salinity (sigma-t) stations are indicated by (●).

Figure 31. T-S presentation of hydrographic data from the Cruises 6 and 7; 5 and 6 December 1974. Each profile is identified with an appropriate number, which contains the cruise number followed by the station number.

Figure 32. T-S presentation of hydrographic data from Cruises 9 and 10; 18 and 20 December 1974. Each profile is identified with an appropriate number, which contains the cruise number followed by the station number.

Figure 33. T-S presentation of hydrographic data from Cruise 12; 29 December 1974. Each profile is identified by its appropriate station number.

Figure 34. T-S presentation of hydrographic data from Cruise 14; 3 January 1975. Each profile is identified by its appropriate station number.

Figure 35. Typical Seasonal Variations in the Gulf of Maine T-S Relationship.

A T-S curve for December (——), March (—·—), May (····), and September (----) is shown for both the Gulf of Maine to the left and for the SLOPE WATER to the right. The hatched areas represent the location of measurements made in the study area during 1974 experiment and 1964 by Colton et al (1968).

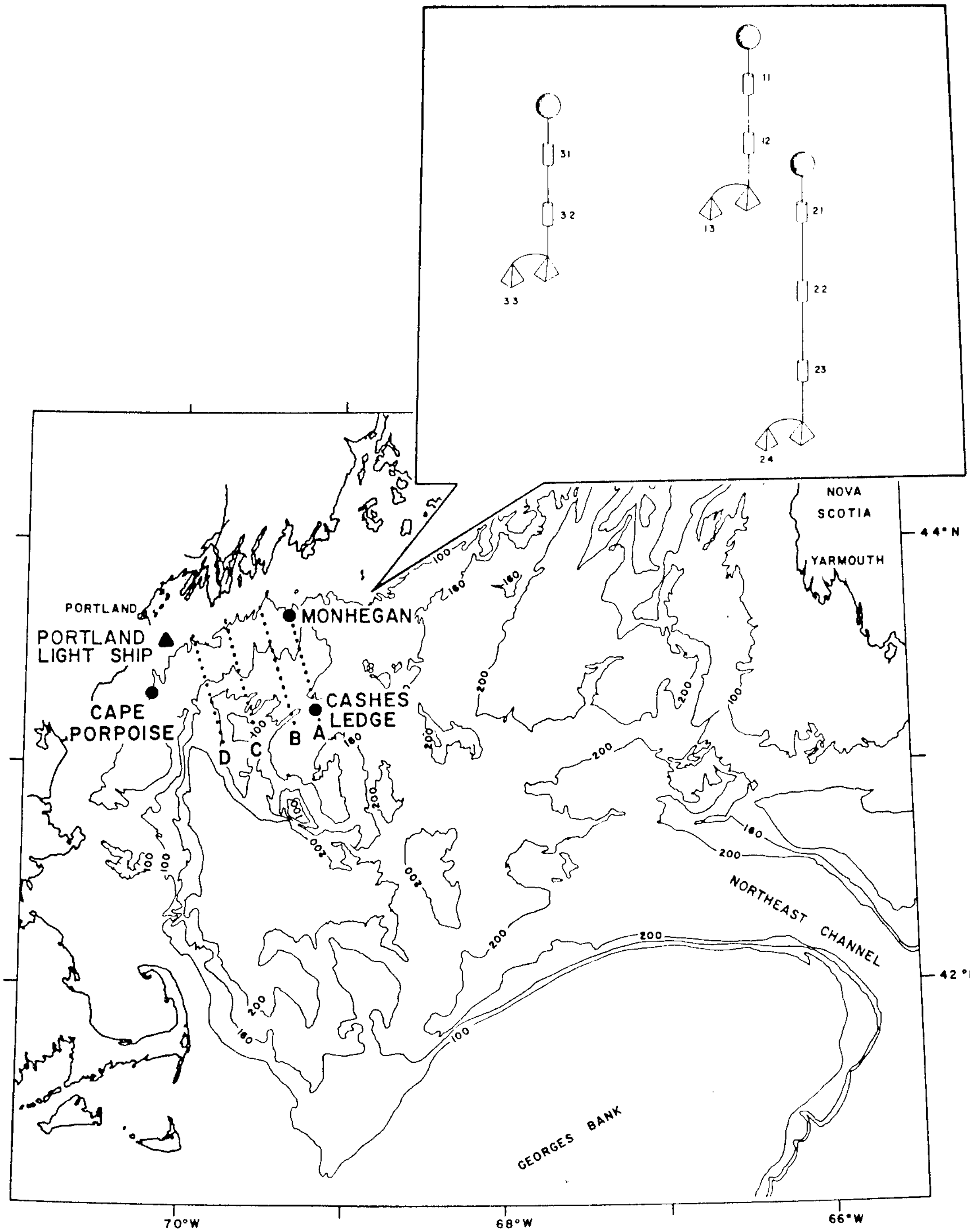


Figure 1 Location Map of the Gulf of Maine

Bottom pressure and temperature and current meter mooring sites for the 1974-75 Gulf of Maine Experiment are indicated by (•) at near Mohegan Island, Cashes Ledge and Cape Porpoise. The insert shows the current meter and bottom pressure / temperature instrument configuration. The principal offshore-onshore hydrographic tracks are identified.

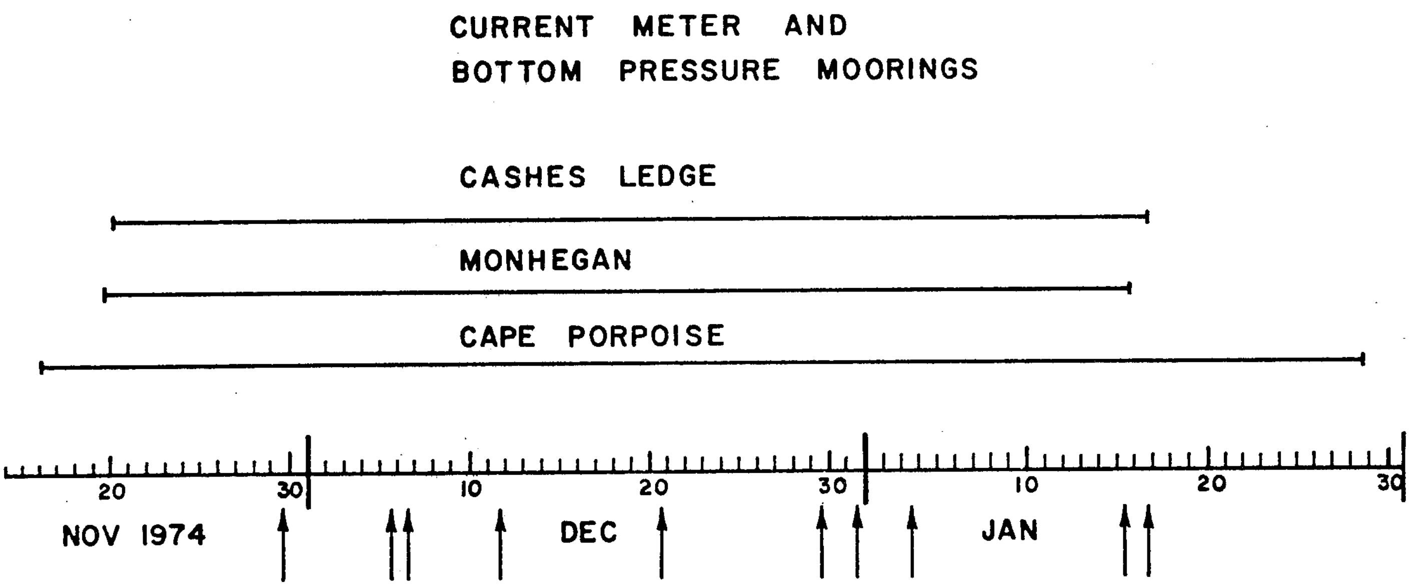


Figure 2. A chronology of activities during the Gulf of Maine Experiment in the winter of 1974-75. The dates of the one day hydrographic cruises are indicated in rlation to the deployment of the moored bottom pressure and current array.

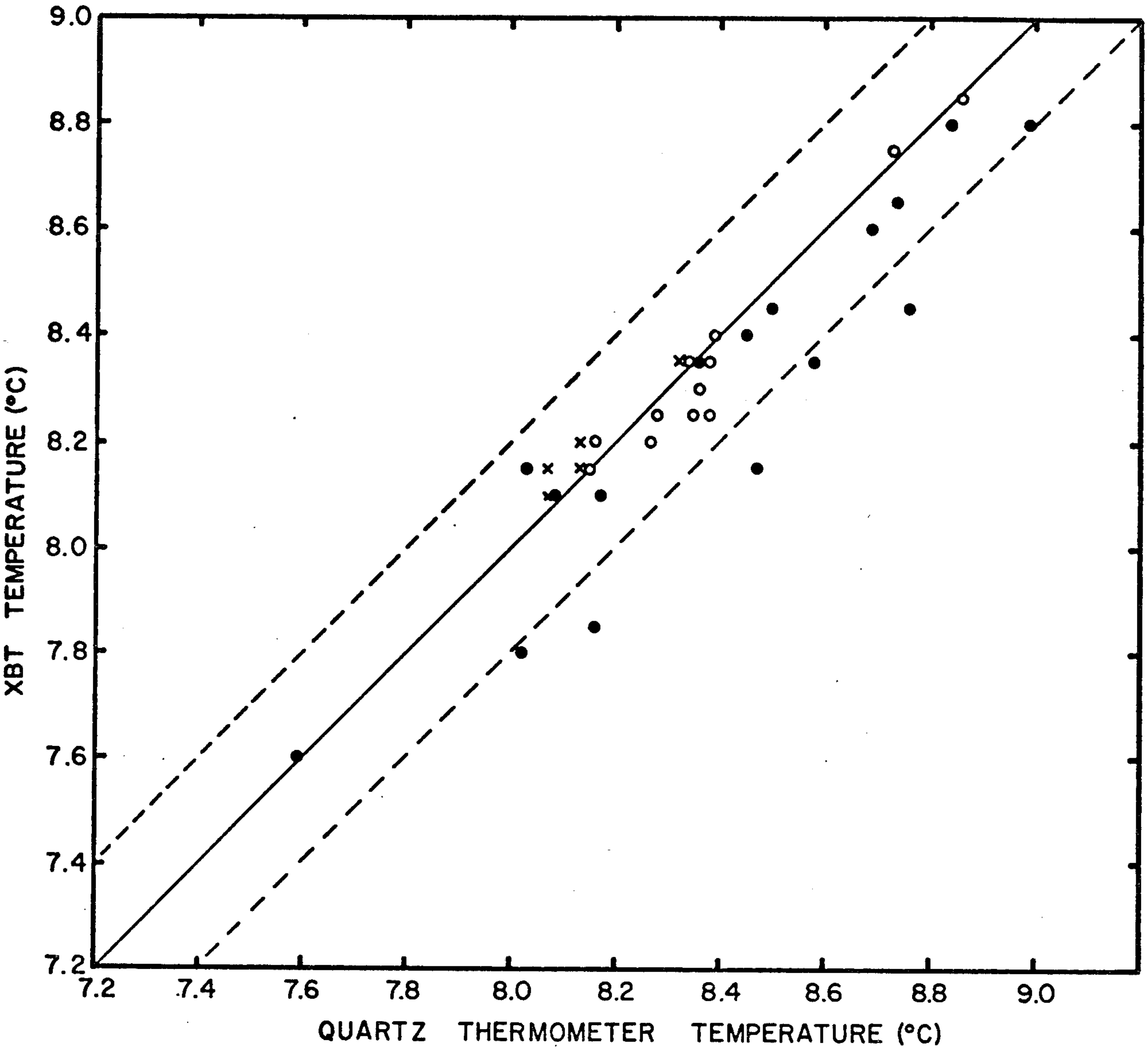
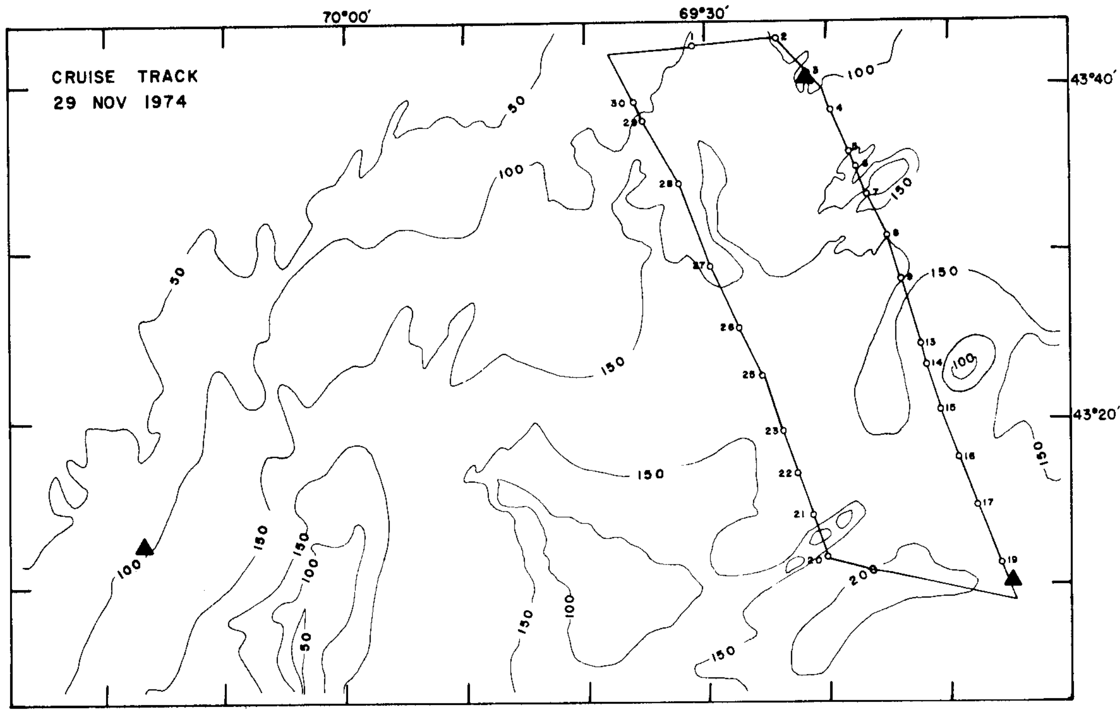


Figure 3. A comparison of quartz thermometer and XBT "surface temperatures" measured at a depth of 1 and 4 meters respectively. This representative example comes from a day of low surface cooling during which T9 (●), T10 (X), and T6 (o) XBTs were deployed. The manufacturer's uncertainty limits (±.2°C) are indicated by the dashed lines. These limits and the clustering suggests that thermistor characteristics are principally responsible for the scatter.



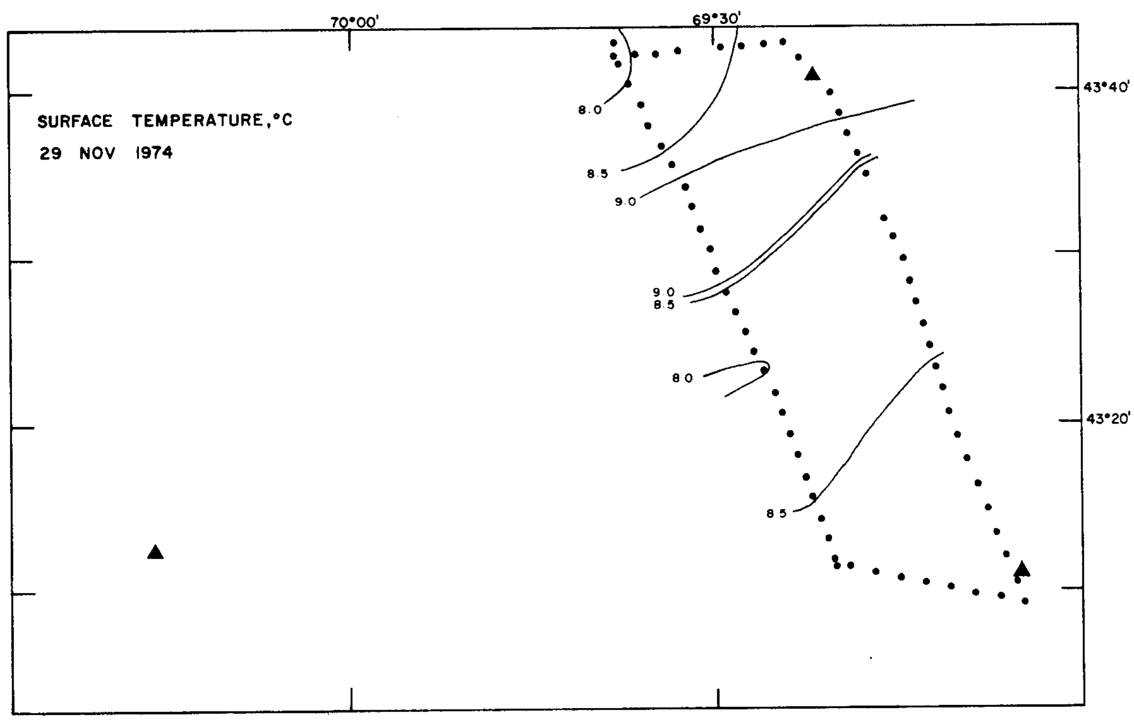
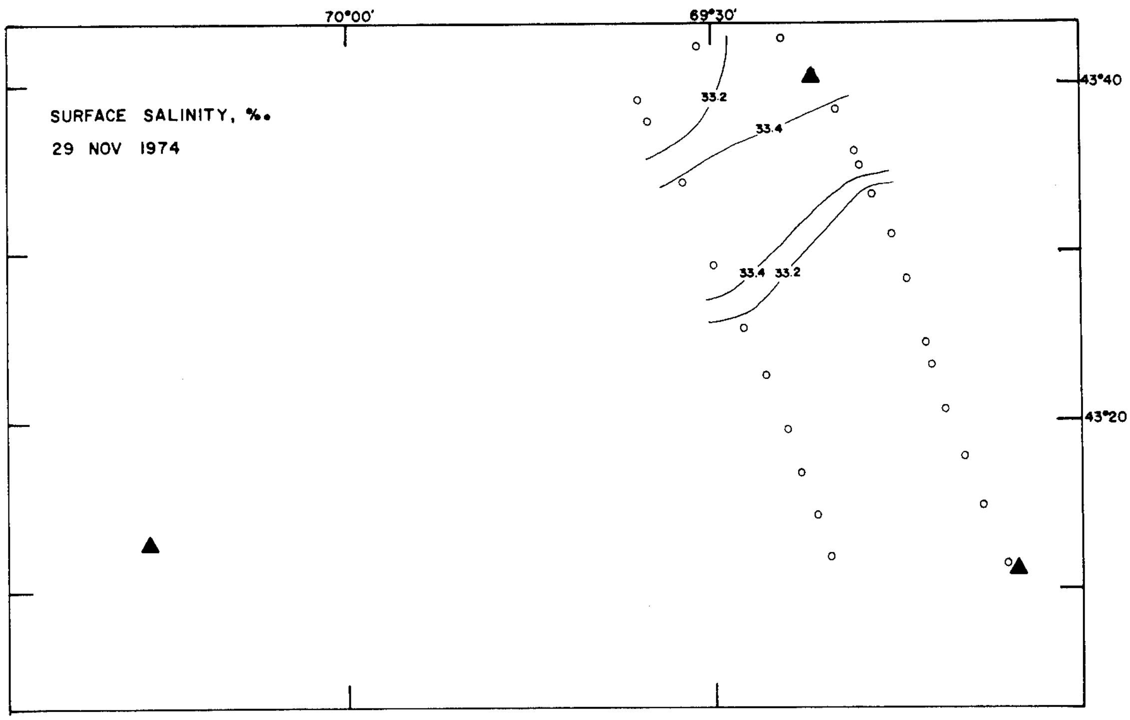


Figure 4 (a & b). The cruise track and surface temperature field respectively for Cruise 5; 29 November 1974. The bottom bathymetry is expressed in meters, the locations of XBT stations are indicated by (o); surface temperatures by (●); and the moored array by (▲).



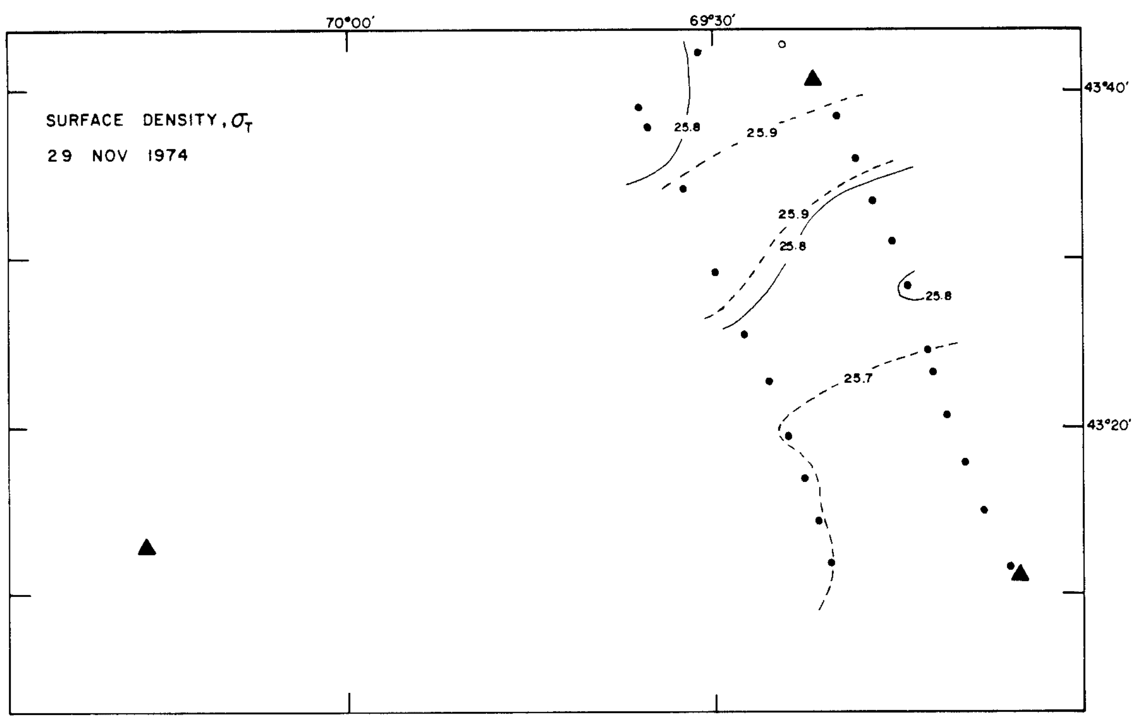


Figure 5 (a & b). The surface salinity and density fields respectively for Cruise 5; 29 November 1974. The locations of surface salinity stations is indicated by (o), the surface density by (●), and the moored array by (▲).

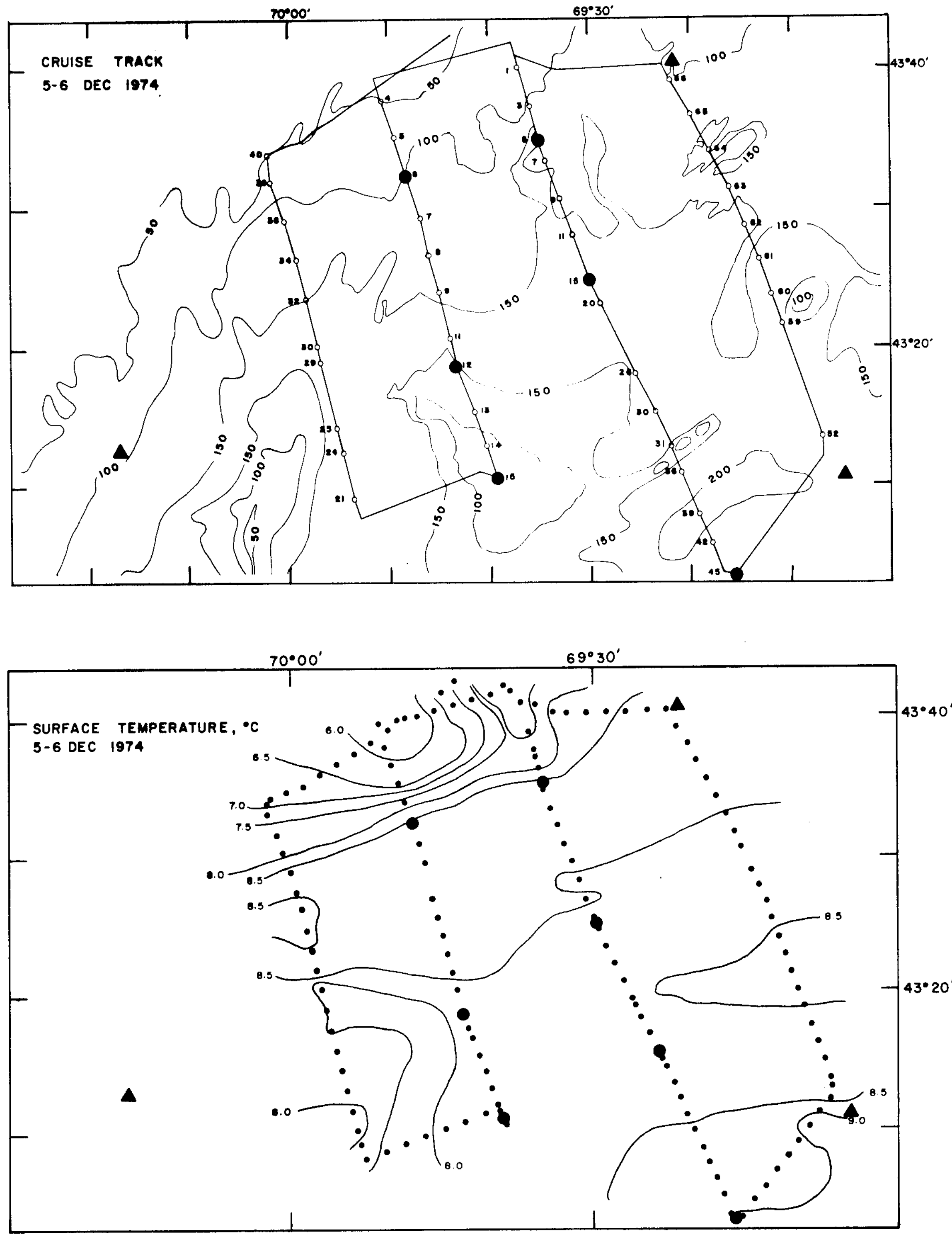
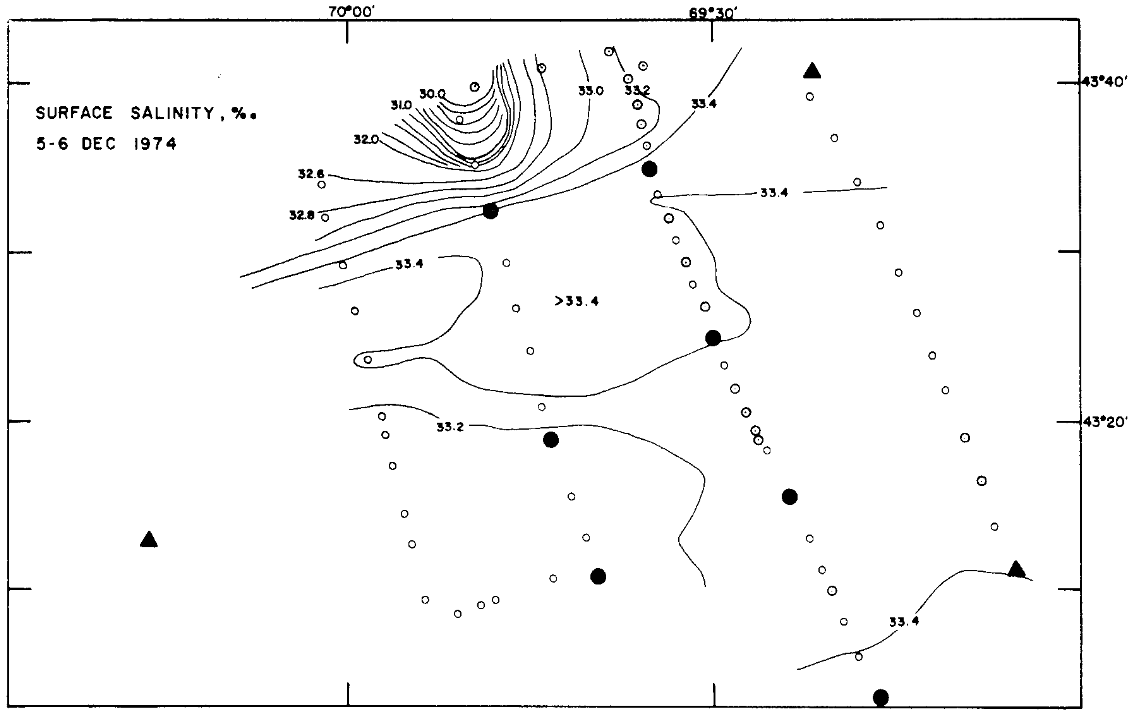


Figure 6 (a & b). The combined cruise tracks and surface temperature field respectively for Cruises 6 and 7; 5 and 6 December 1974. The bottom bathymetry is expressed in meters, the locations of XBT stations are indicated by (o); hydrographic stations by (●); surface temperatures by (•); and the moored array by (▲).



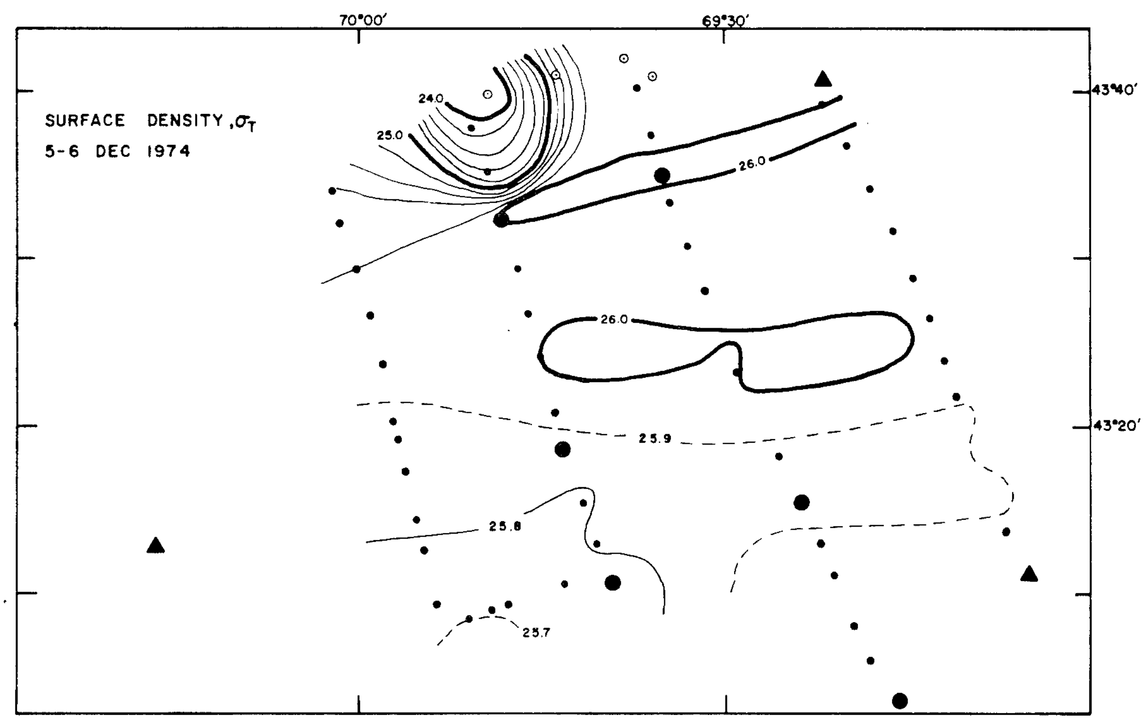


Figure 7 (a & b). The combined surface salinity and density fields respectively for cruises 6 and 7; 5 and 6 December 1974. The locations of the surface salinity stations are indicated by (○); hydrographic stations by (⬤); surface densities by (•); and the moored array by (▲).

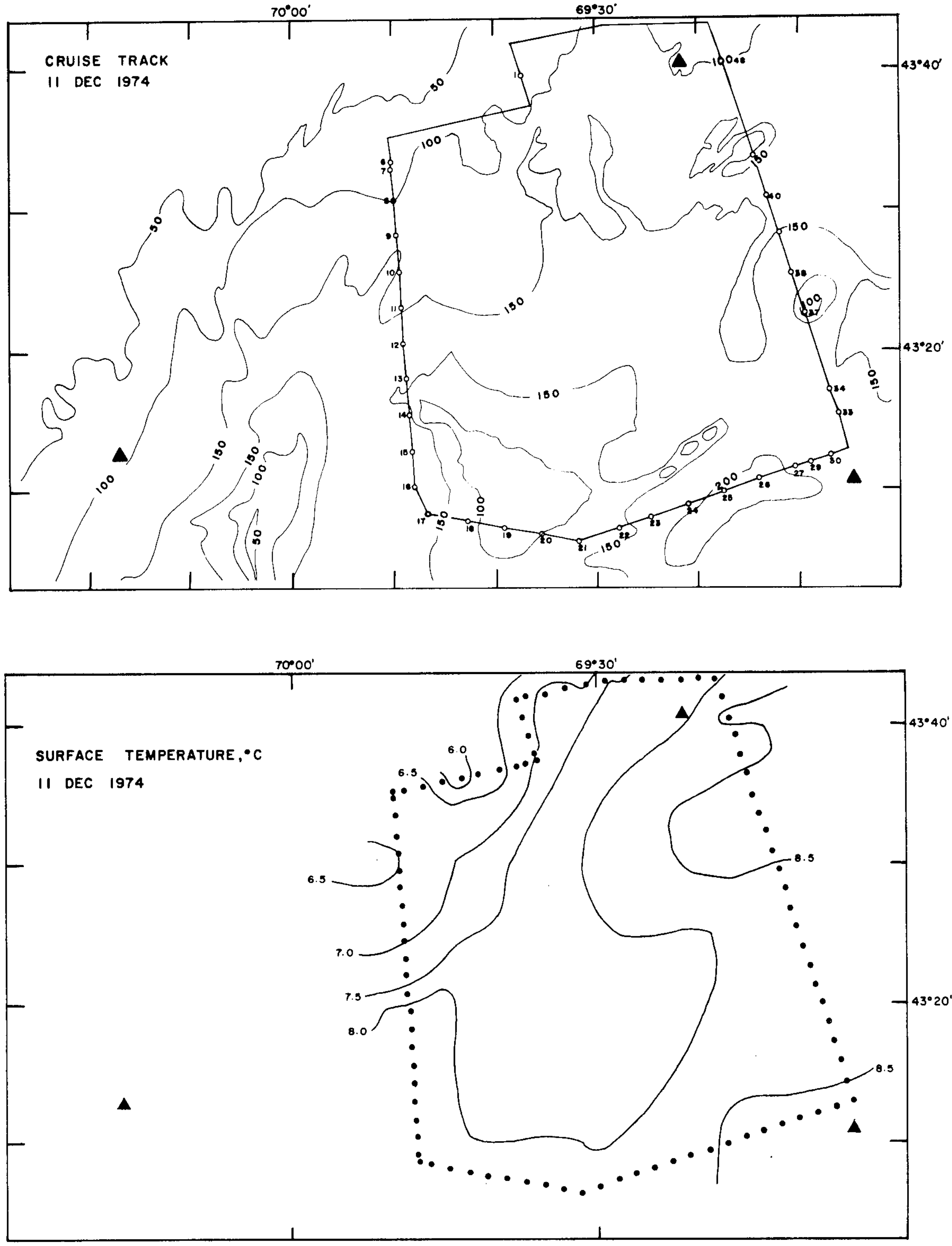
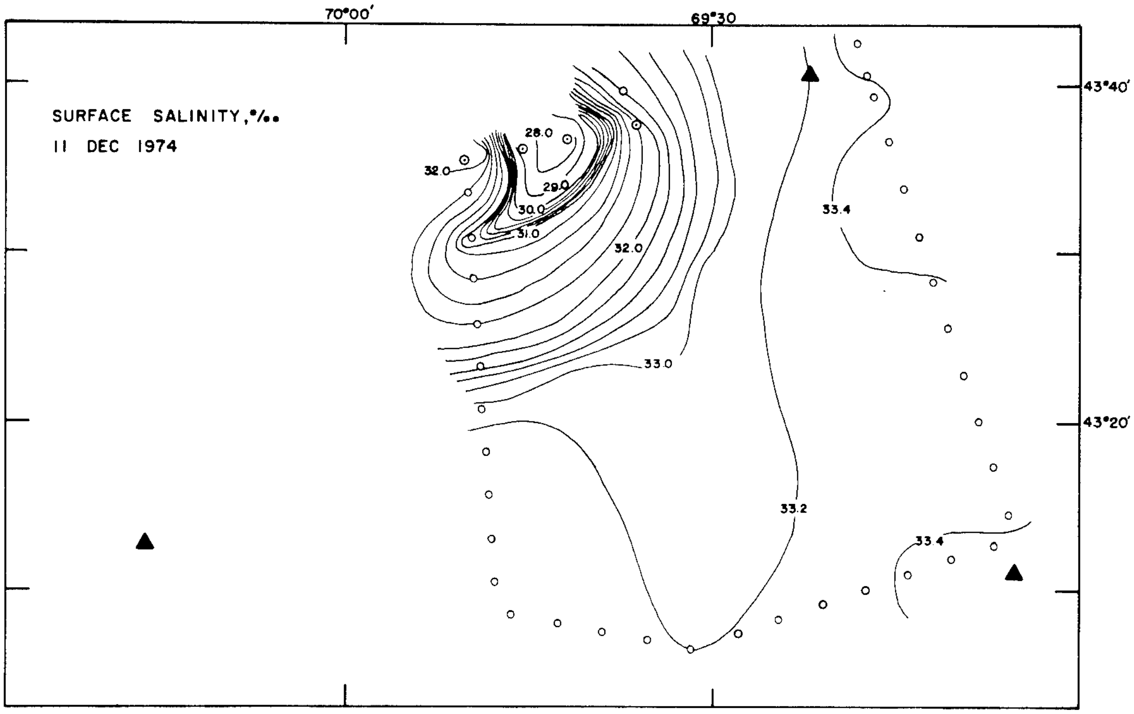


Figure 8 (a & b). The cruise track and the surface temperature field respectively for cruise 8; 11 December 1974. The bottom bathymetry is expressed in meters, the location of the XBT stations is indicated by (o); surface temperatures by (●); and the moored array by (▲).



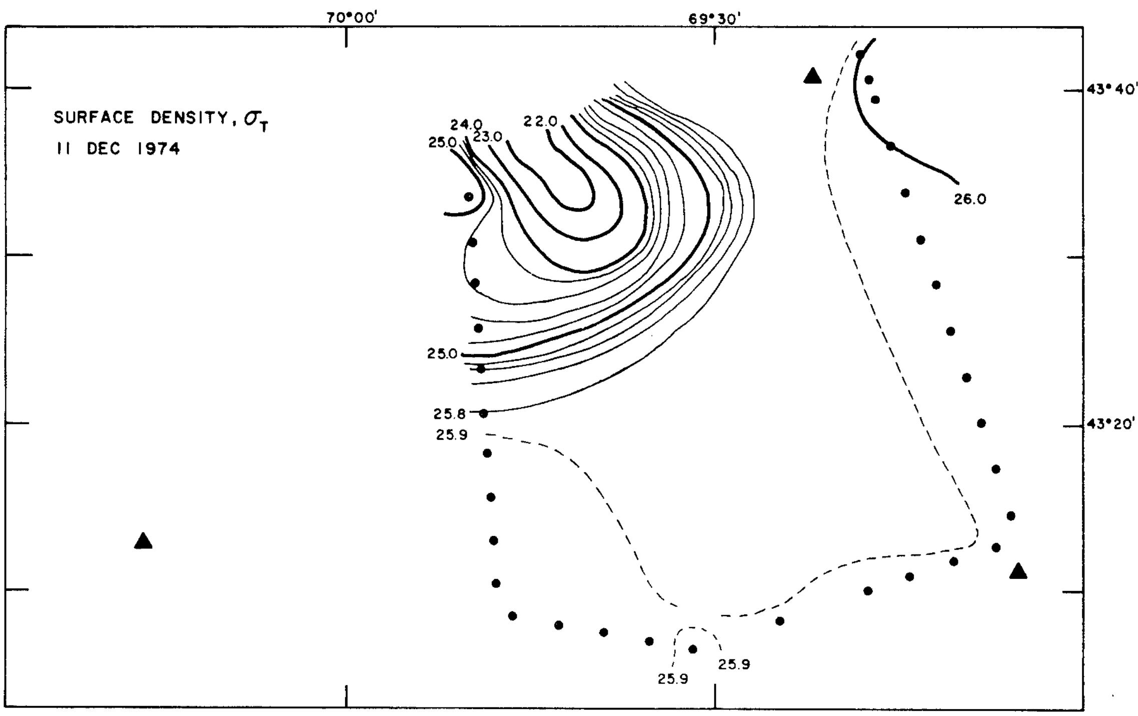


Figure 9 (a & b). The surface salinity and density fields respectively for cruise 8; 11 December 1974. The locations of the surface salinity stations are indicated by (o); surface densities by (●); and the moored array by (▲).

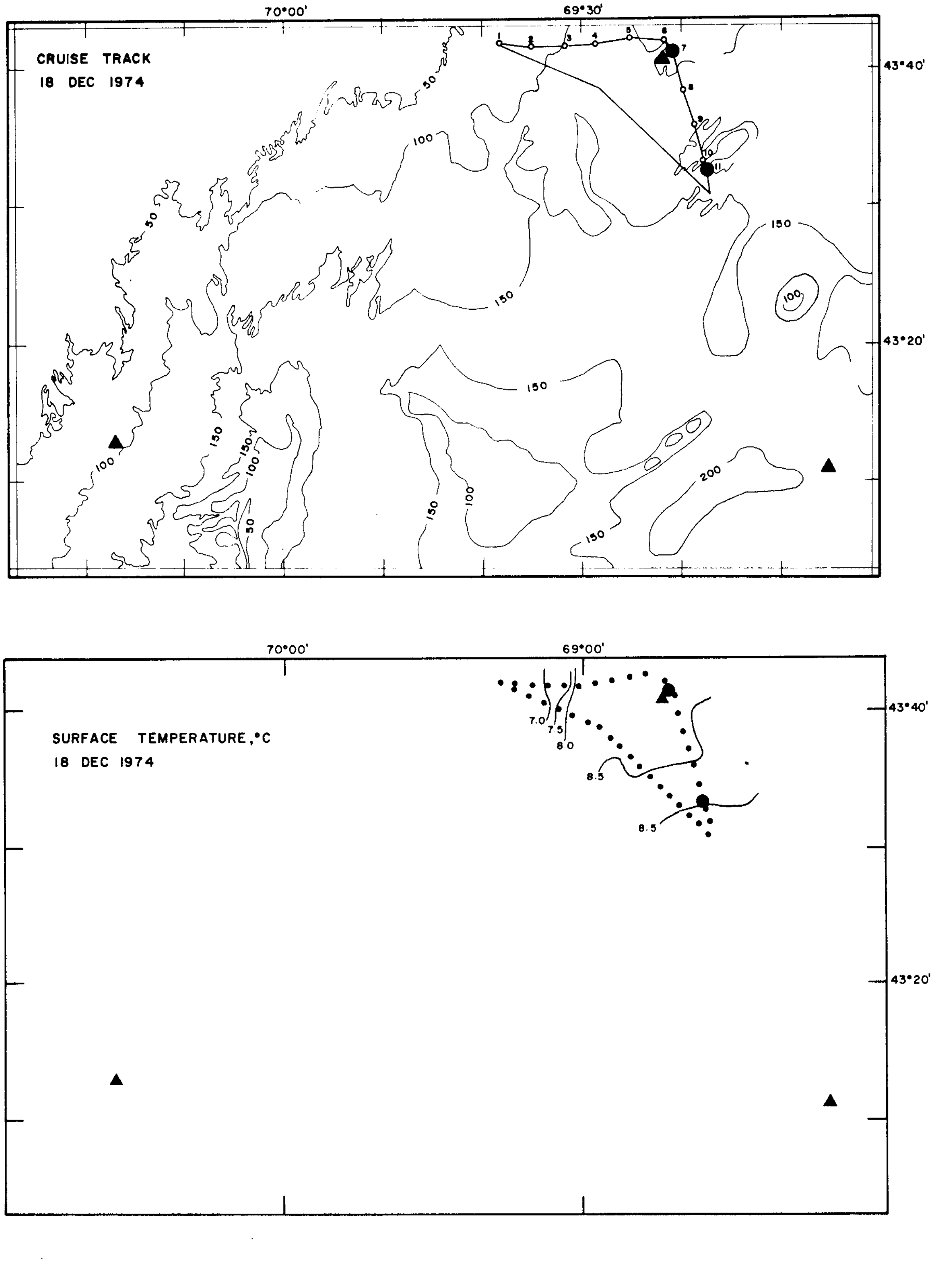
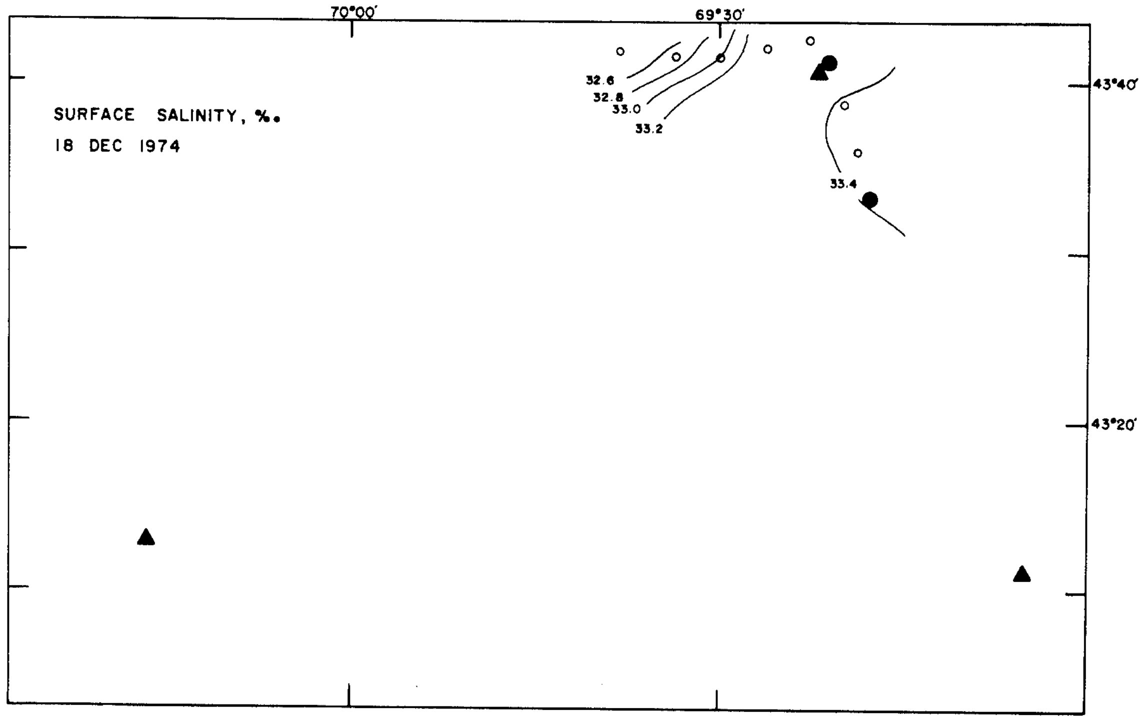


Figure 10. The surface temperature field for cruise 9; 18 December 1974. The locations of the surface temperature stations are indicated by (●); hydrographic stations by (⬤); and the moored array by (▲).



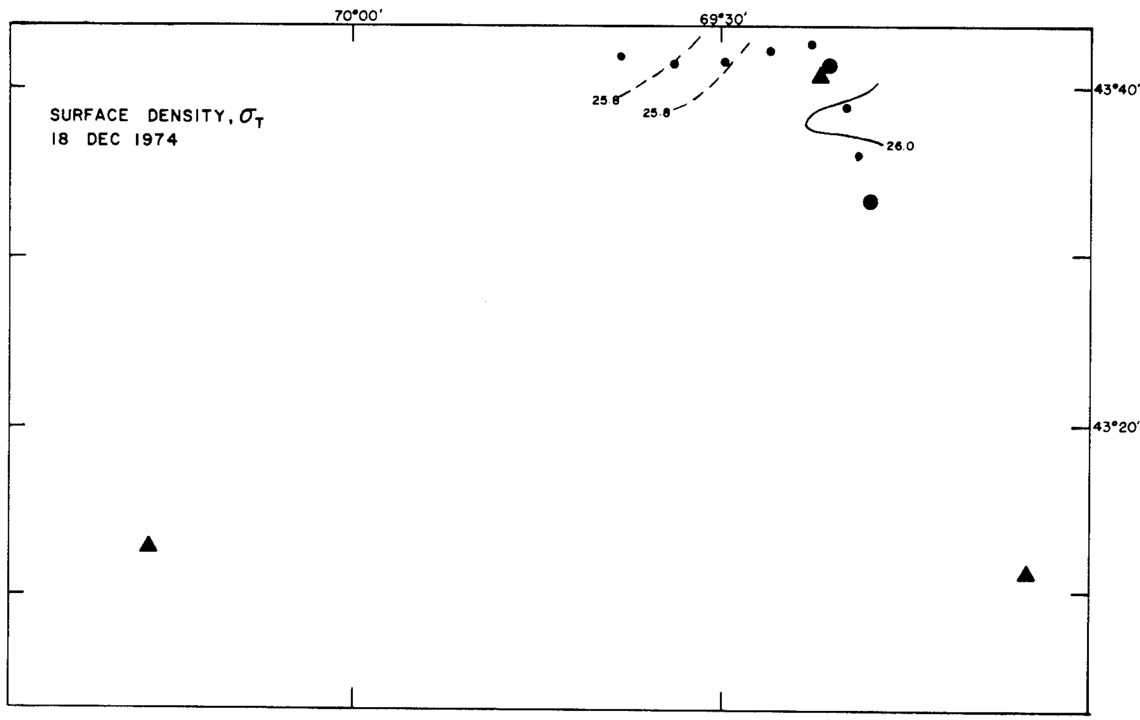


Figure 11 (a & b). The surface salinity and density fields respectively for cruise 9; 18 December 1974. The locations of the surface salinity stations are indicated by (○); hydrographic stations by (●); and the moored array by (▲).

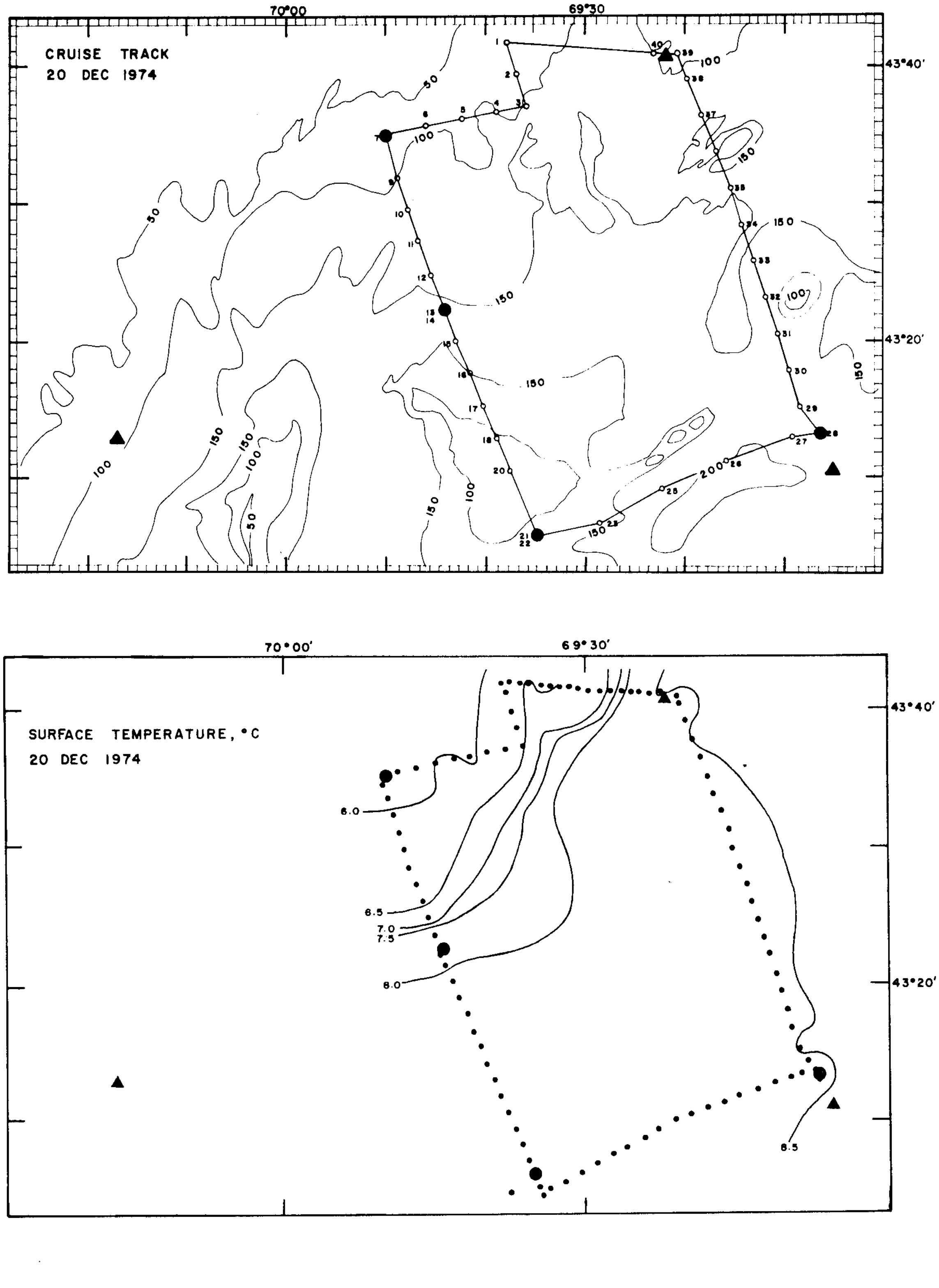
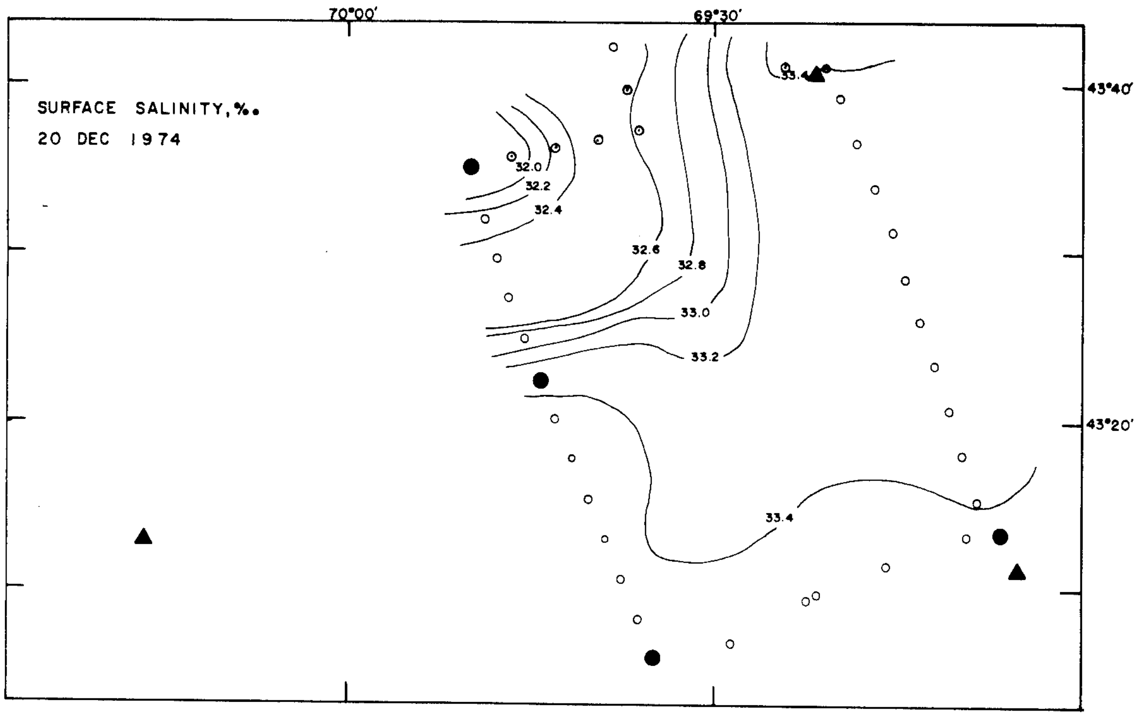


Figure 12 (a & b). The cruise track and surface temperature field respectively for cruise 10; 20 December 1974. The bottom bathymetry is expressed in meters, the location of the XBT stations is indicated by (o); surface salinity and temperature only by (⊙); hydrographic stations (⬤); surface temperatures by (•); and the moored array by (▲).



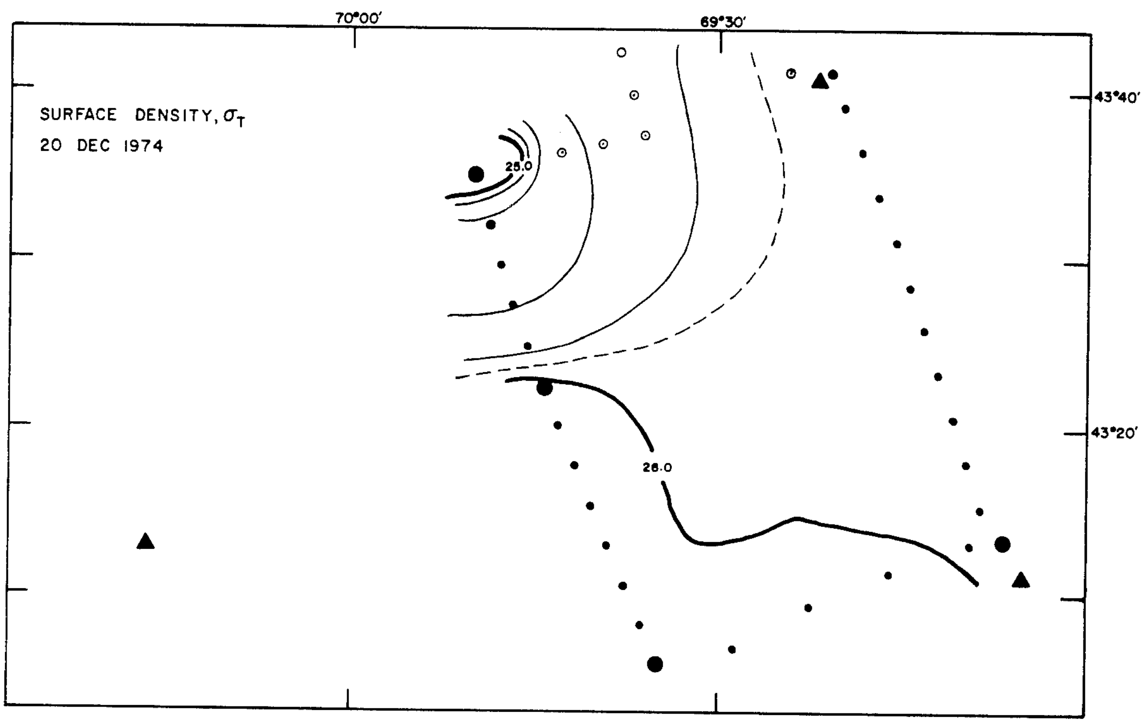


Figure 13 (a & b). The surface salinity and density field respectively for cruise 10; 20 December 1974. The location of the surface salinity stations is indicated by (o); hydrographic stations by (●); surface densities by (•); and the moored array by (▲).

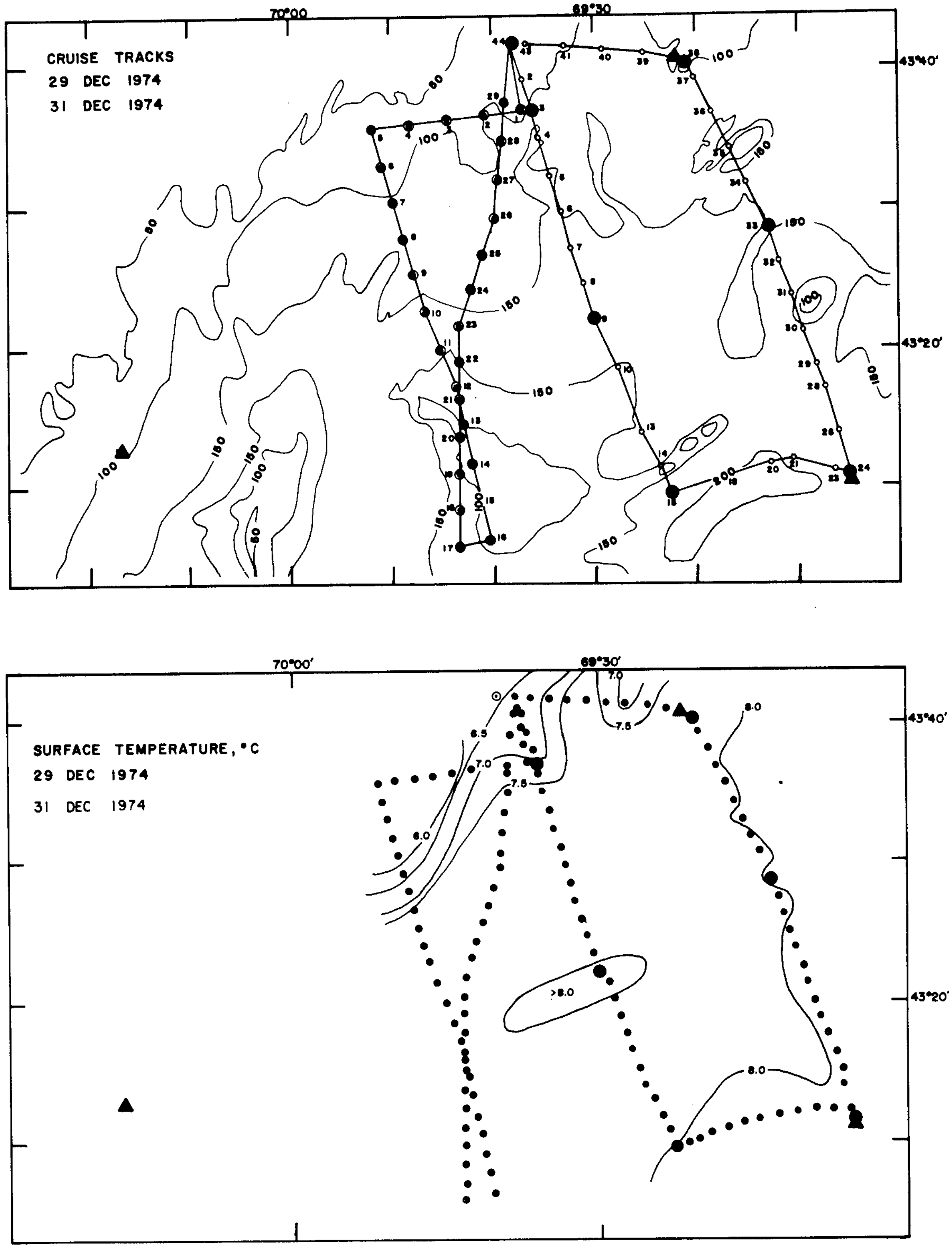


Figure 14 (a & b). The combined cruise track and surface temperature field respectively for cruises 12 and 13; 29 and 31 December 1974. The bottom bathymetry is expressed in meters, the locations of the XBT stations are indicated by (o); hydrographic stations (●); surface salinity and temperature only by (⊙); temperatures by (•); and the moored array by (▲).

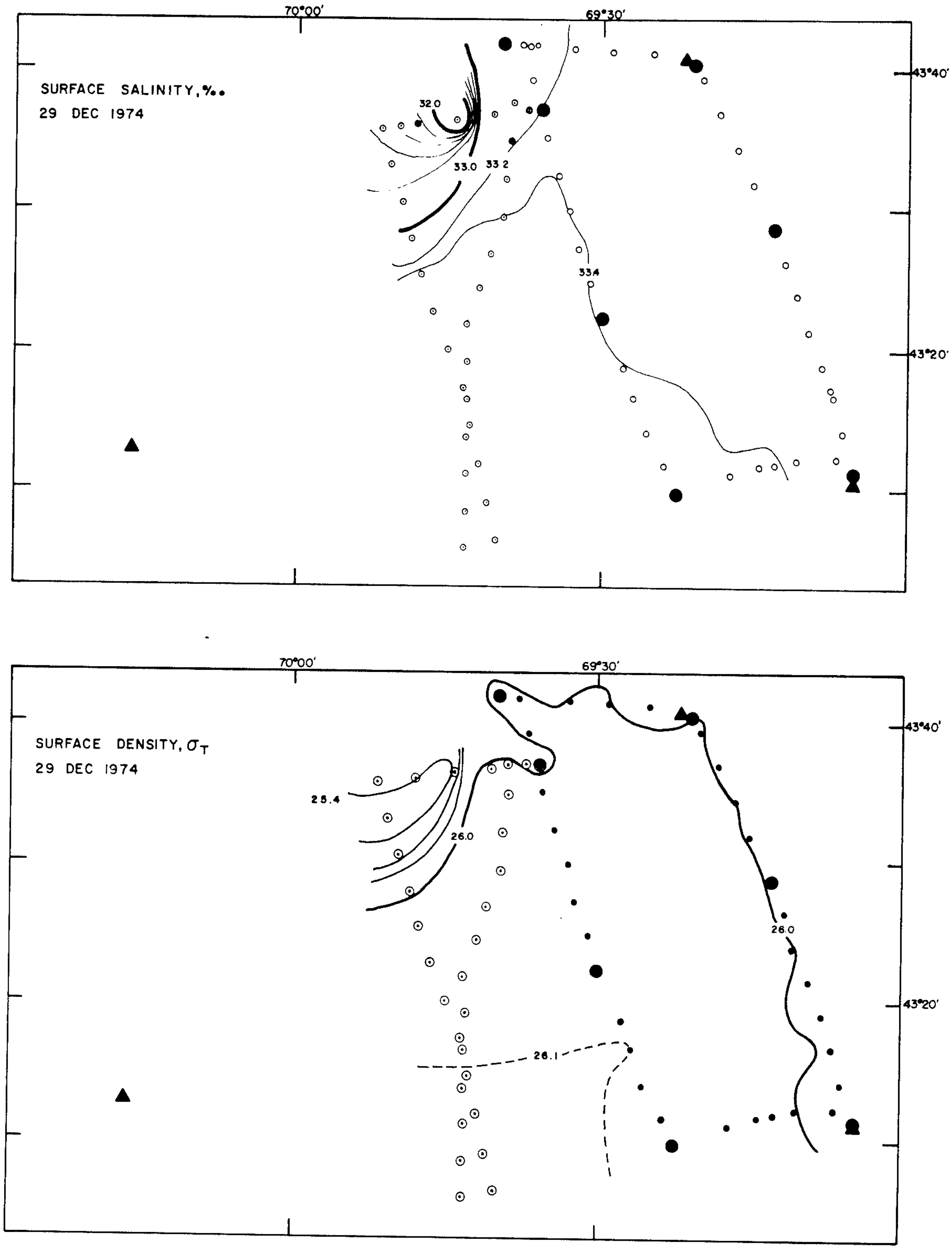


Figure 15 (a & b). The combined surface salinity and density fields respectively for Cruises 12 and 13; 29 and 31 December 1974. The locations of the surface salinity stations are indicated by (o); hydrographic stations by (⬤); surface densities by (•); and the moored array by (▲).

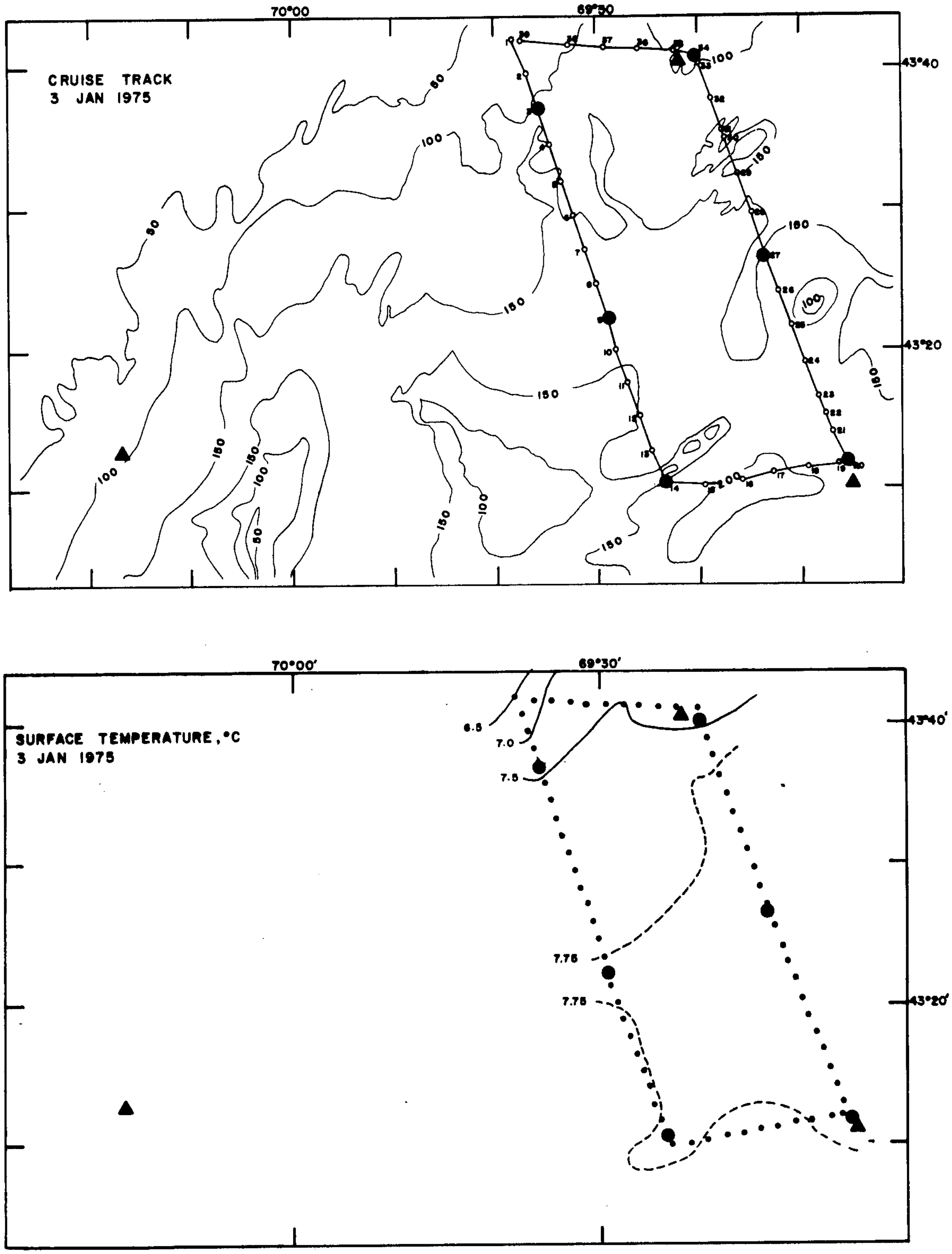


Figure 16 (a & b). The cruise track and surface temperature field respectively for cruise 14; 3 January 1975. The bottom bathymetry is expressed in meters and the locations of the XBT stations are indicated by (o); hydrographic stations (●); surface temperatures by (•); and the moored array by (▲).

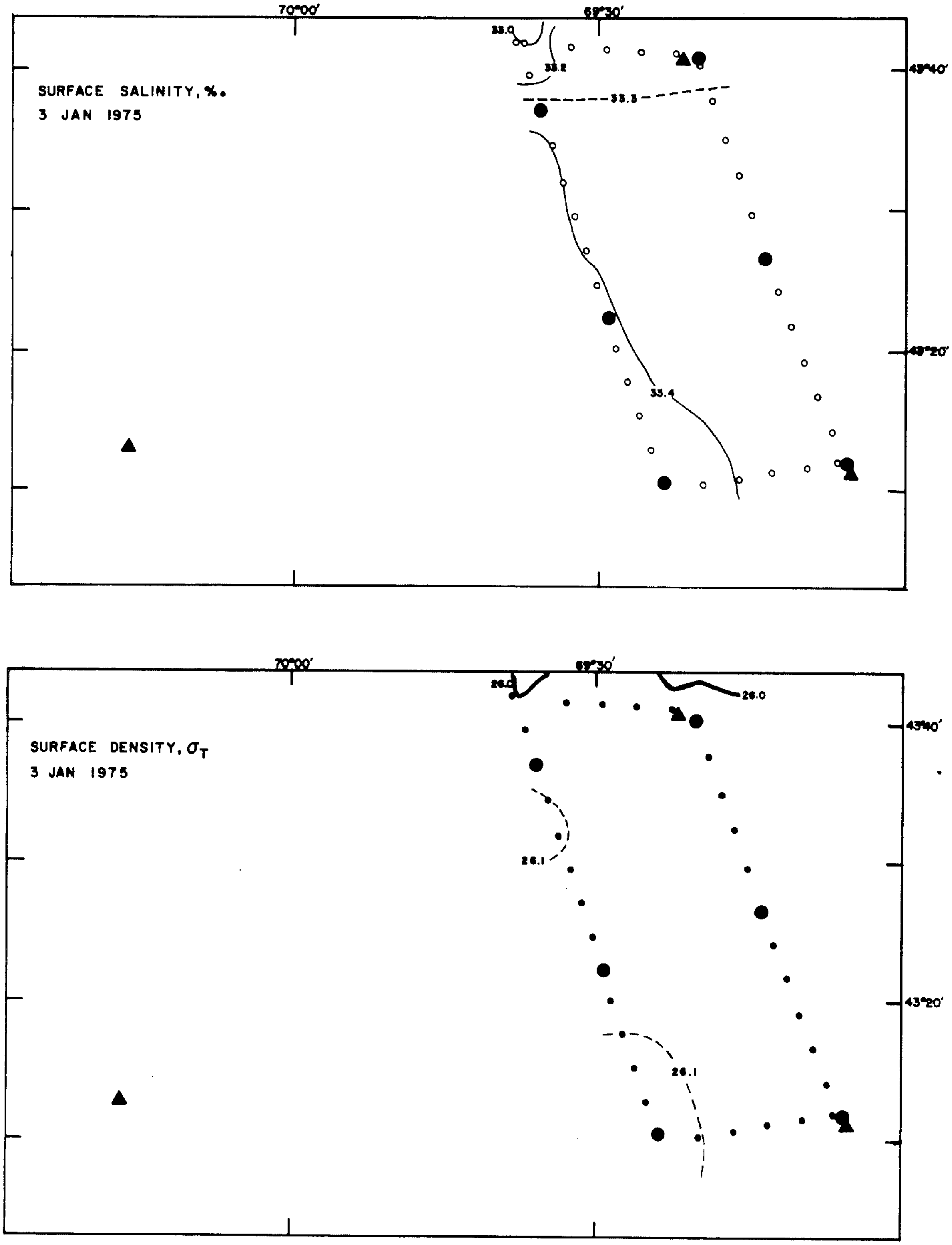


Figure 17 (a & b). The surface salinity and density fields respectively for Cruise 14; 3 January 1975. The locations of the surface salinity stations are indicated by (○); hydrographic stations by (⬤); surface densities by (•); and the moored array by (▲).

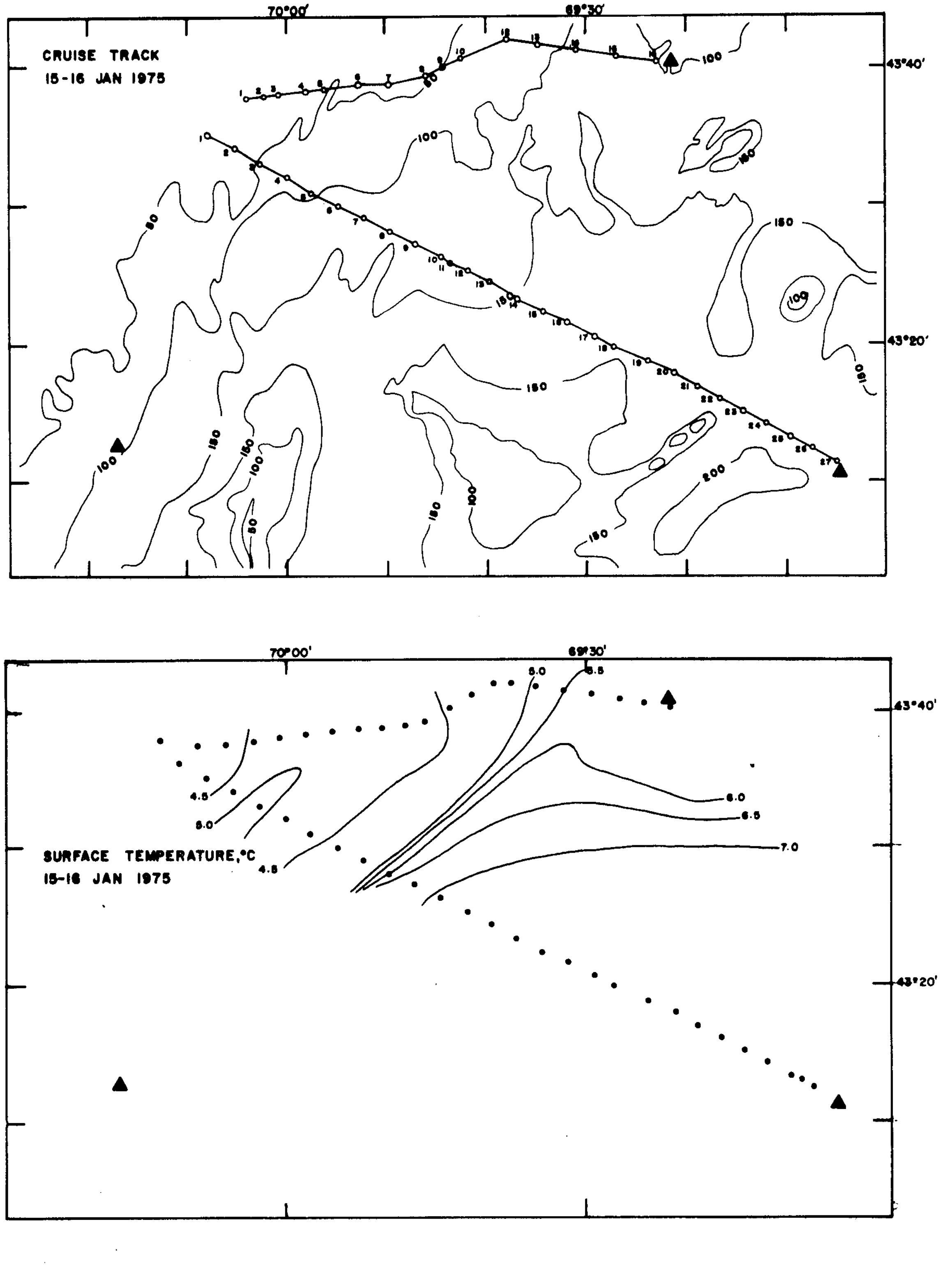


Figure 18 (a & b). The combined cruise track and surface temperature field respectively for Cruises 15 and 16; 15 and 16 January 1975. The bottom bathymetry is expressed in meters and the locations of the surface salinity stations is indicated by (o); surface temperatures by (●); and the moored array by (▲).

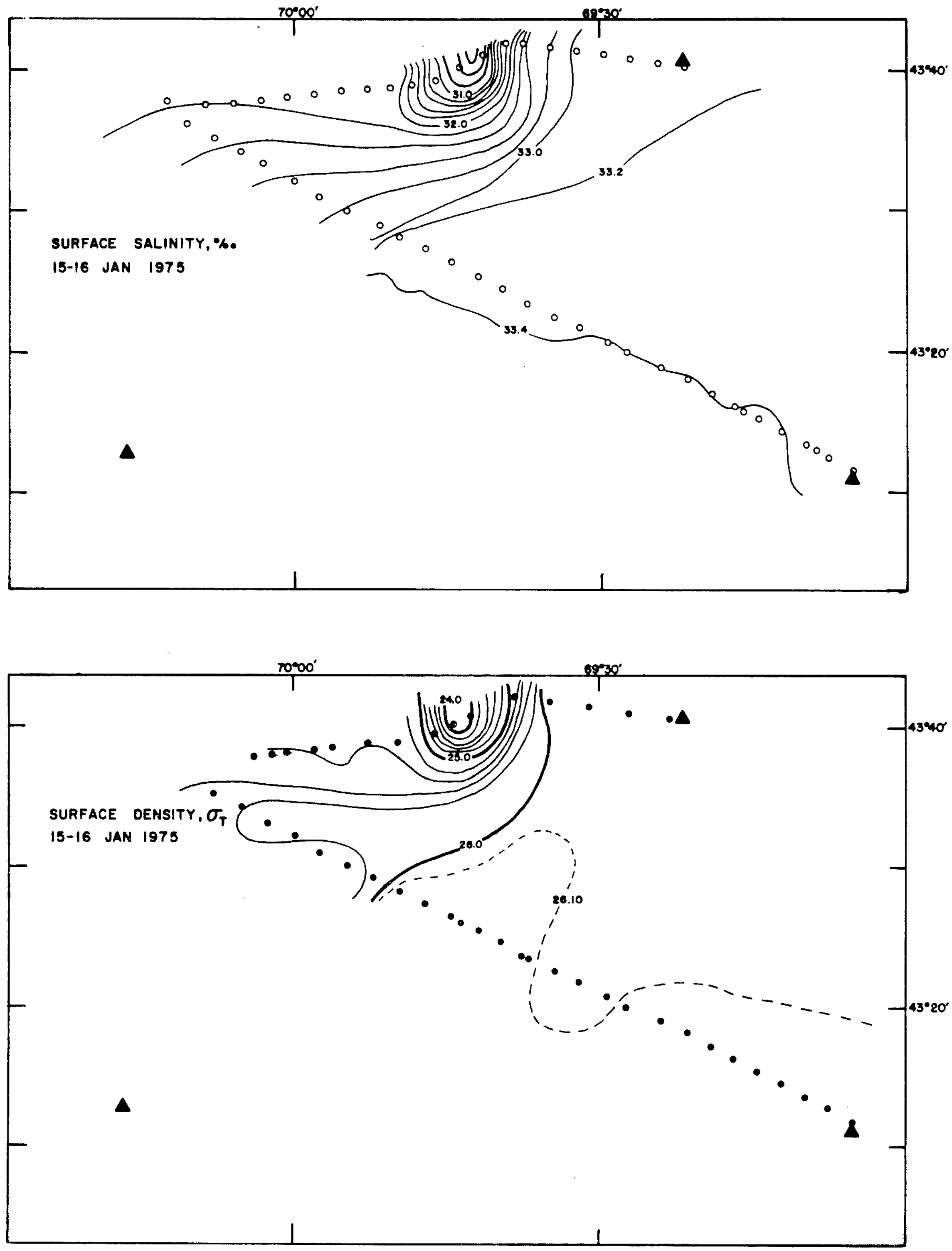


Figure 19 (a & b). The combined surface salinity and density fields respectively for cruises 15 and 16 respectively; 15 and 16 January 1975. The locations of the salinity stations are indicated by (o); surface densities by (●); and the moored array by (▲).

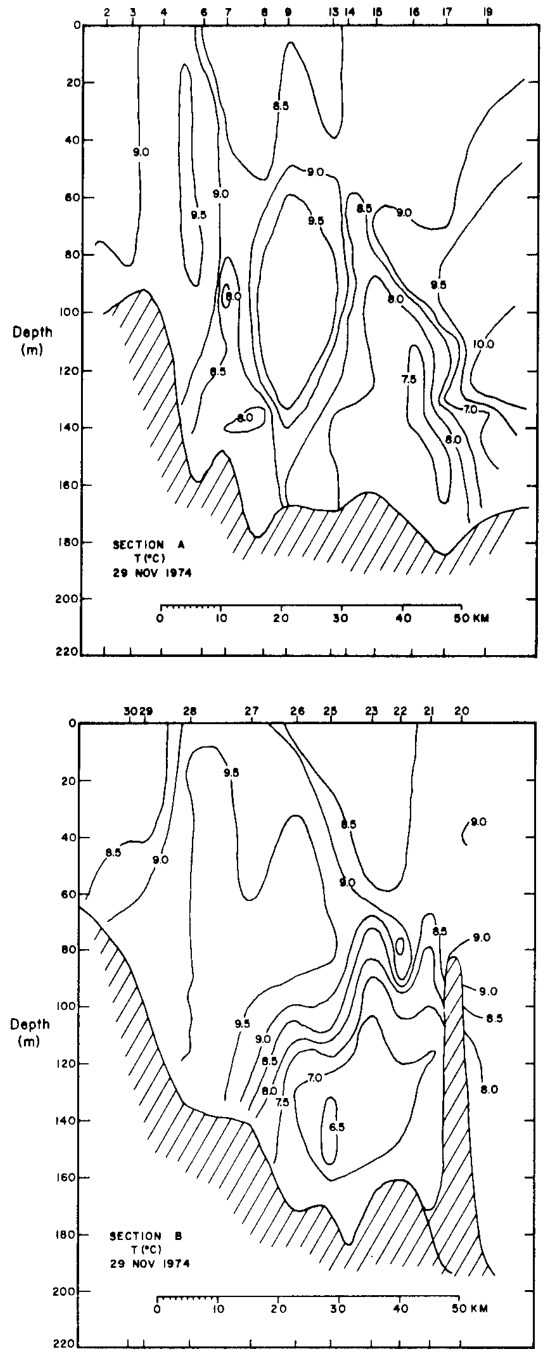


Figure 20. Track A and B temperature sections (above and below respectively), which were made during the offshore and inshore legs of cruise 5; 29 November 1974.

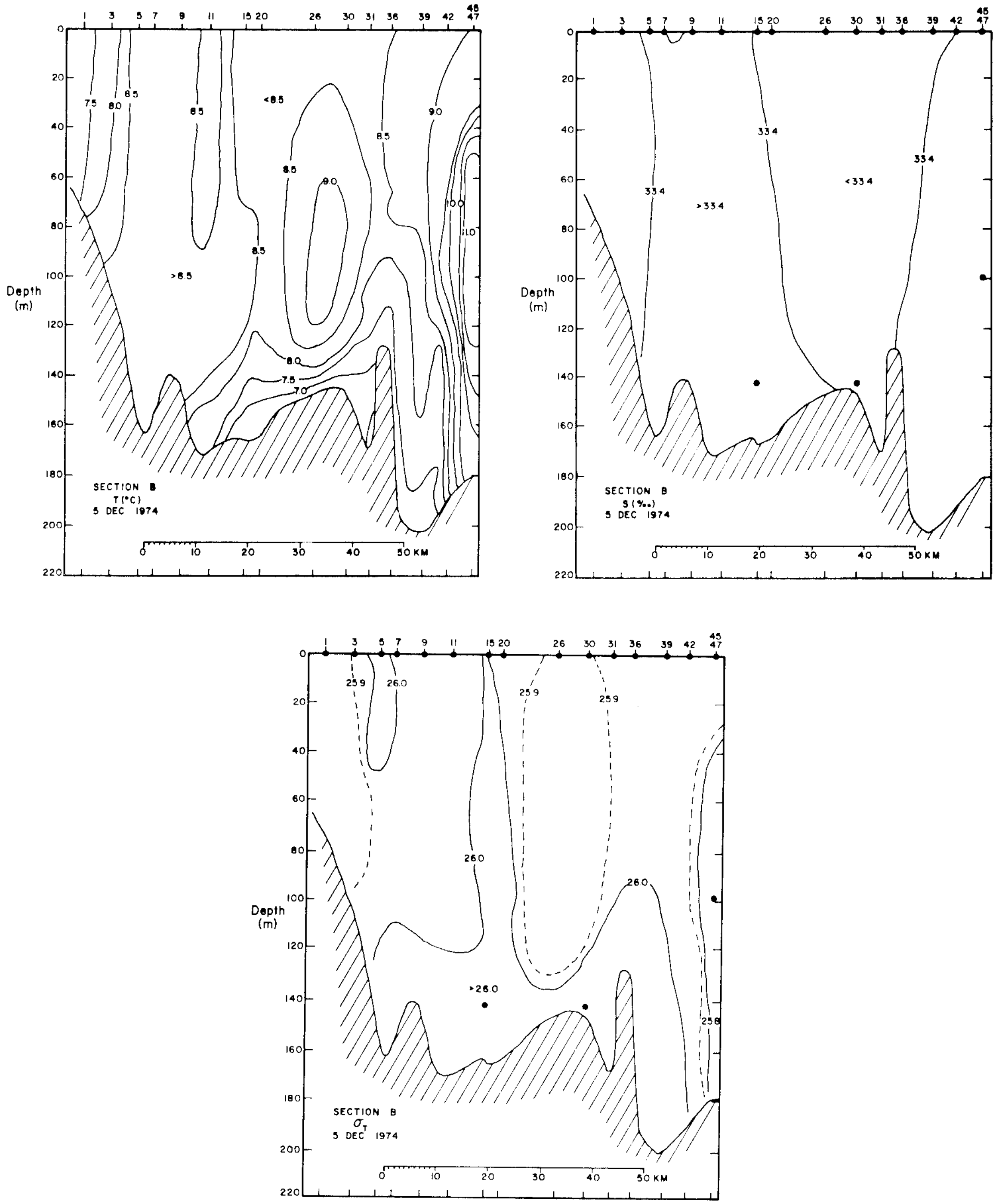


Figure 21. Track B temperature, salinity, and sigma-t sections which was made on the offshore leg of Cruise 6; 5 December 1974. The salinity (sigma-t) stations are indicated by (●).

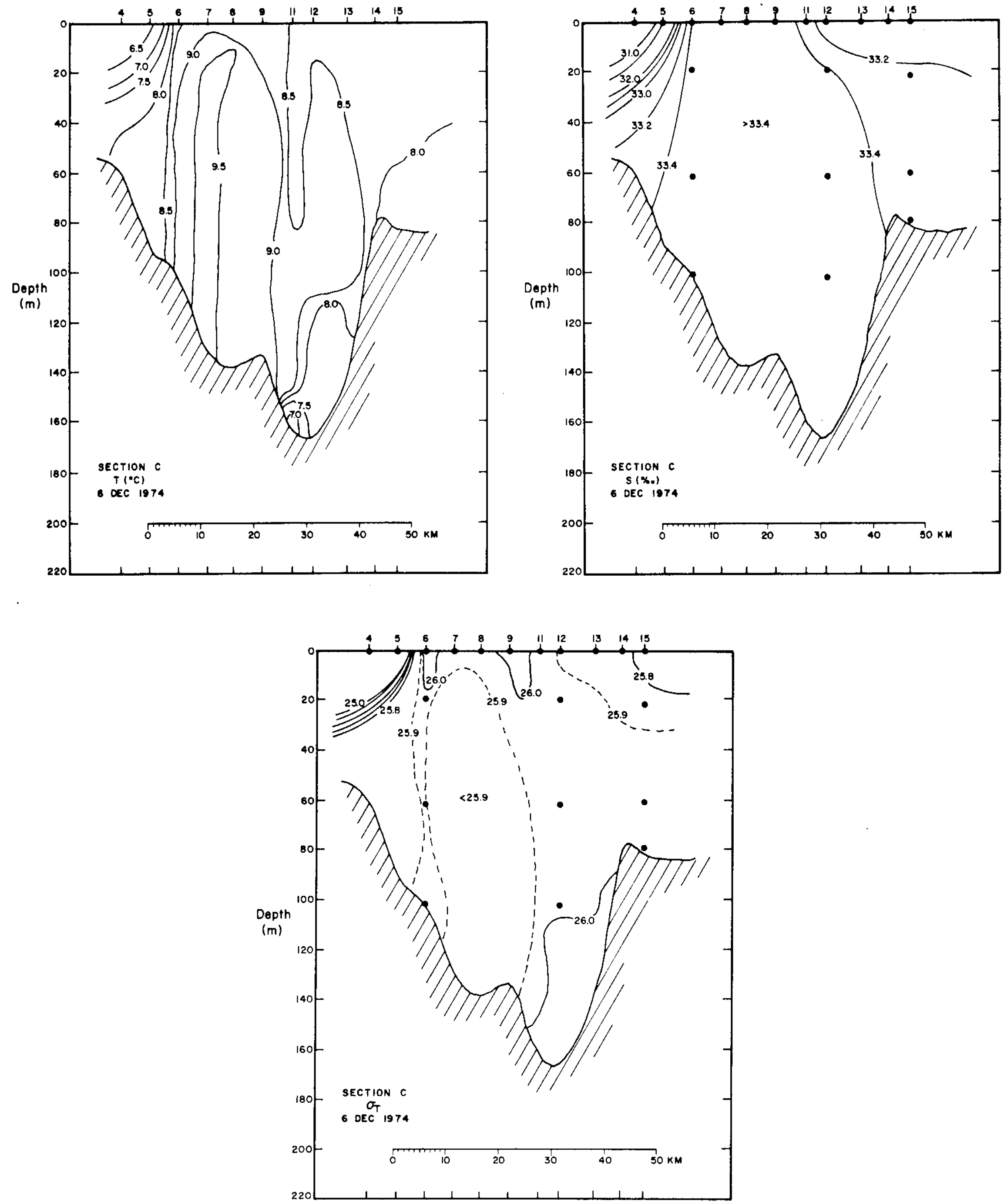


Figure 22. Track C temperature, salinity, and sigma-t sections, which were made on the offshore leg of Cruise 7; 6 December 1974. The salinity (sigma-t) stations are indicated by (●).

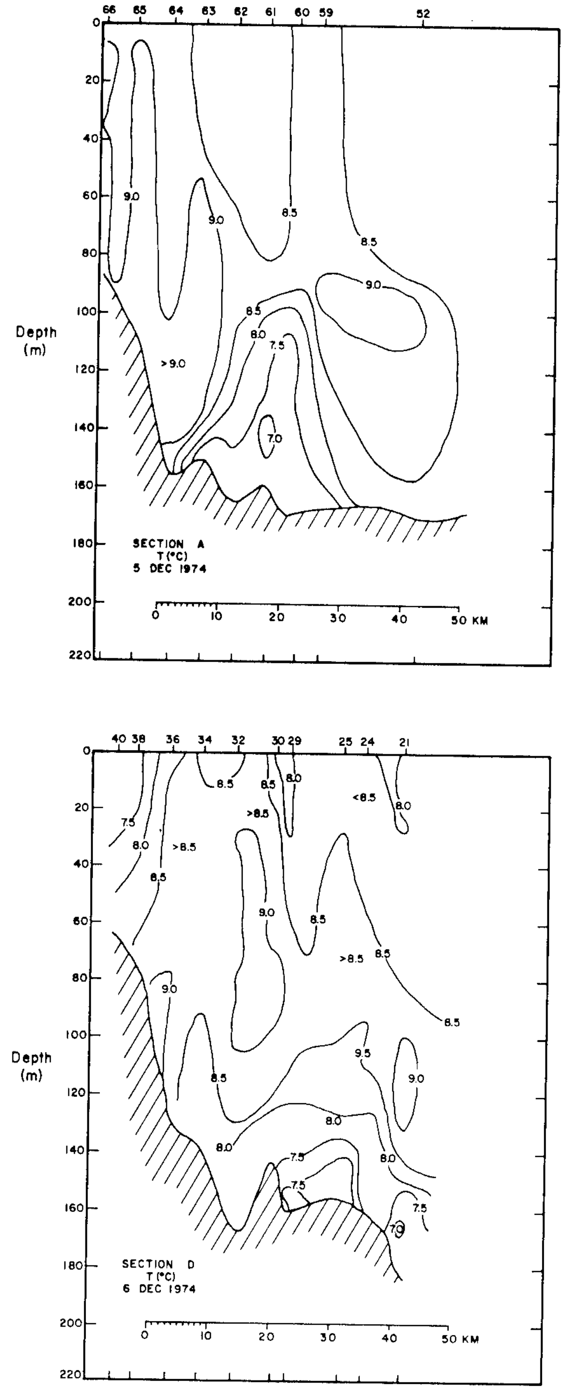


Figure 23. Track A and D temperature sections (above and below respectively) which were made on the inshore legs of Cruises 6 and 7; 5 and 6 December 1974 respectively.

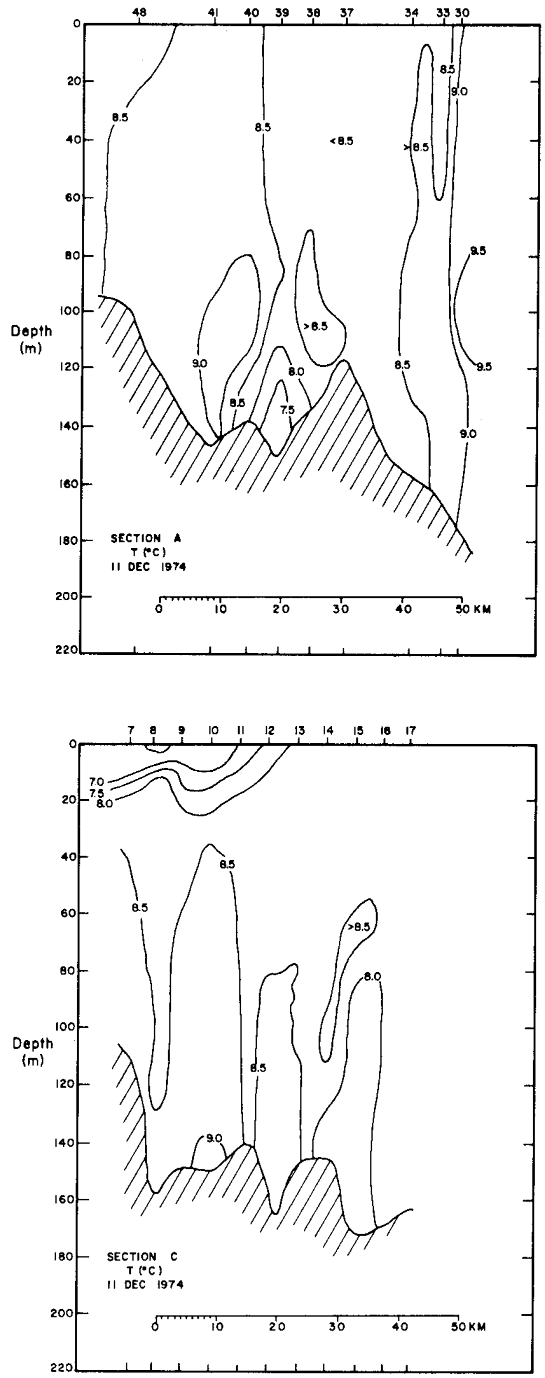


Figure 24. Track A and C temperature sections (above and below respectively), which were made during the inshore and offshore legs of Cruise 8; 11 December 1974.

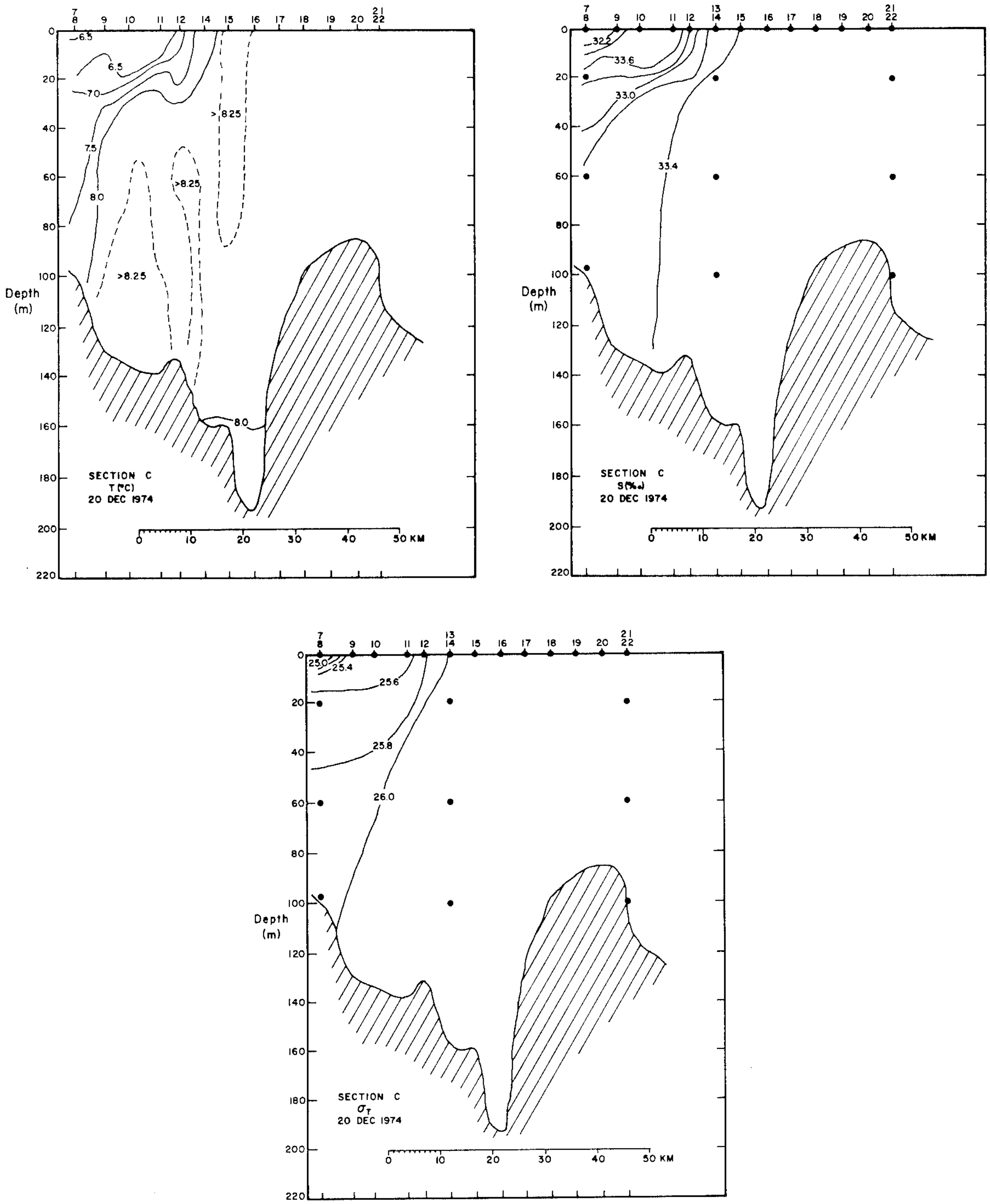


Figure 25. Track C temperature, salinity, and sigma-t sections, which were made during the offshore leg of Cruise 10; 20 December 1974. The salinity (sigma-t) stations are indicated by (●).

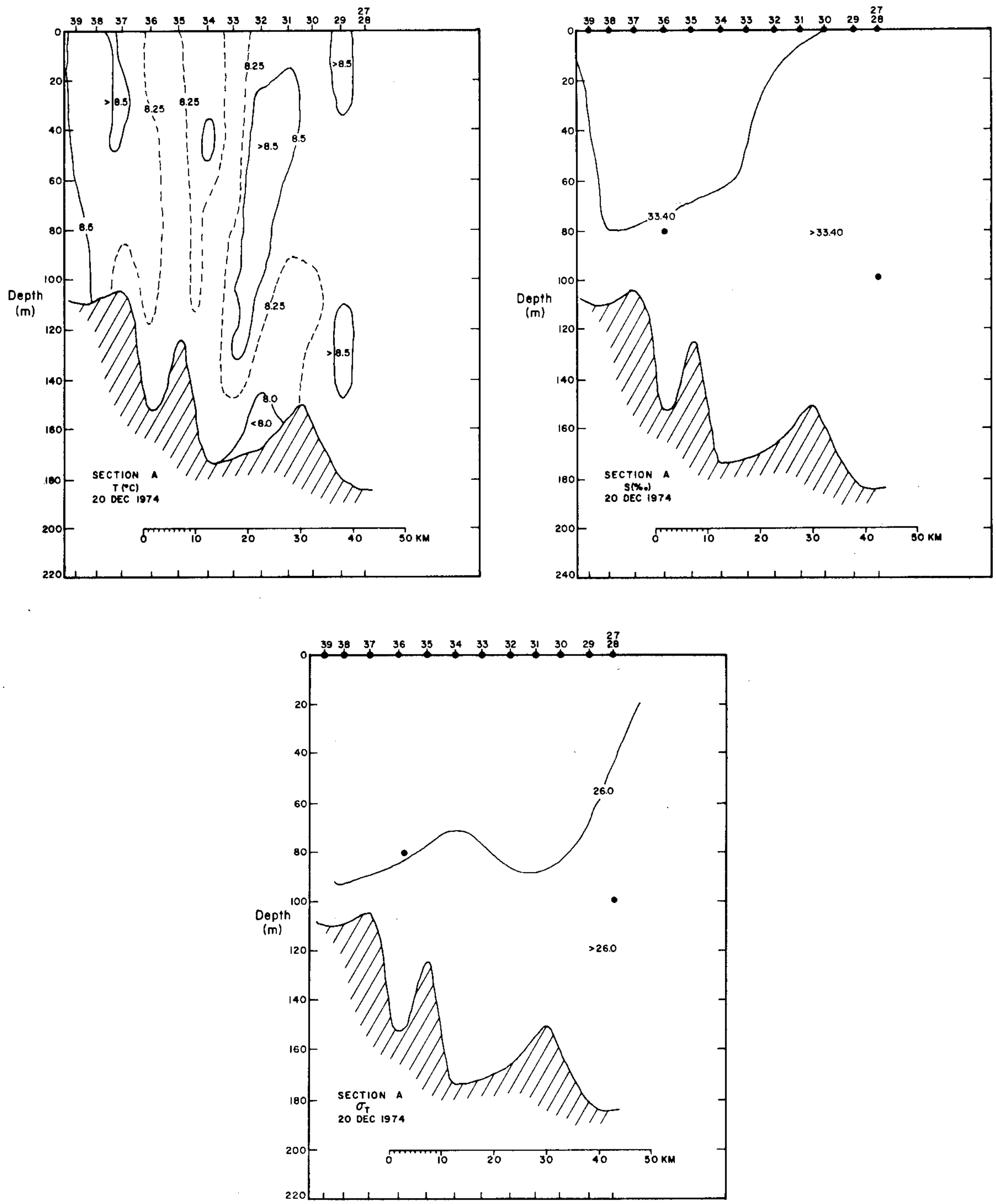


Figure 26. Track A temperature, salinity, and sigma-t sections, which were made during the onshore leg of Cruise 10; 20 December 1974. The salinity (sigma-t) stations are indicated by (●).

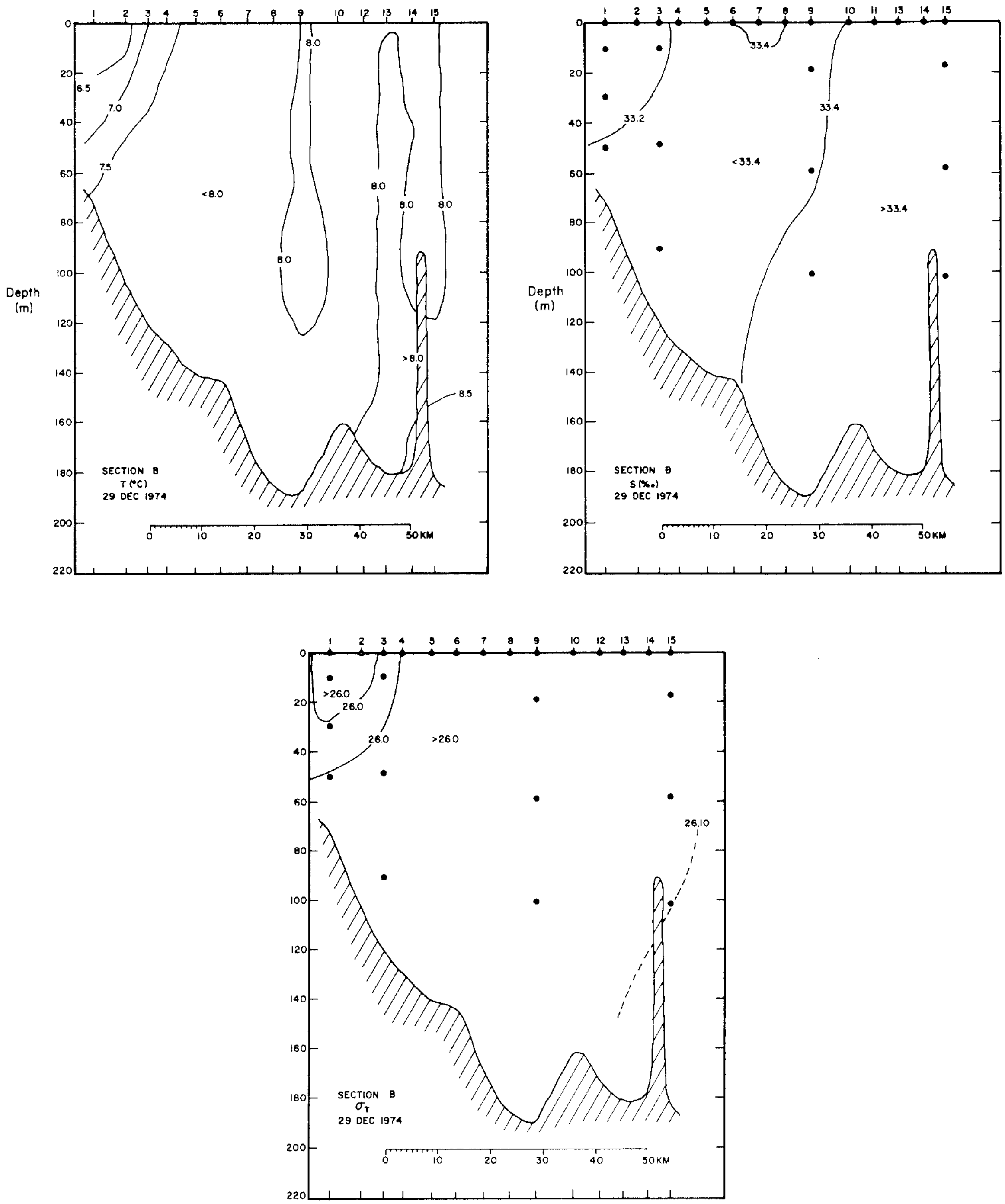


Figure 27. Track B temperature, salinity, and sigma-t sections, which were made during the offshore leg of cruise 12; 29 December 1974. The salinity (sigma-t) stations are indicated by (●).

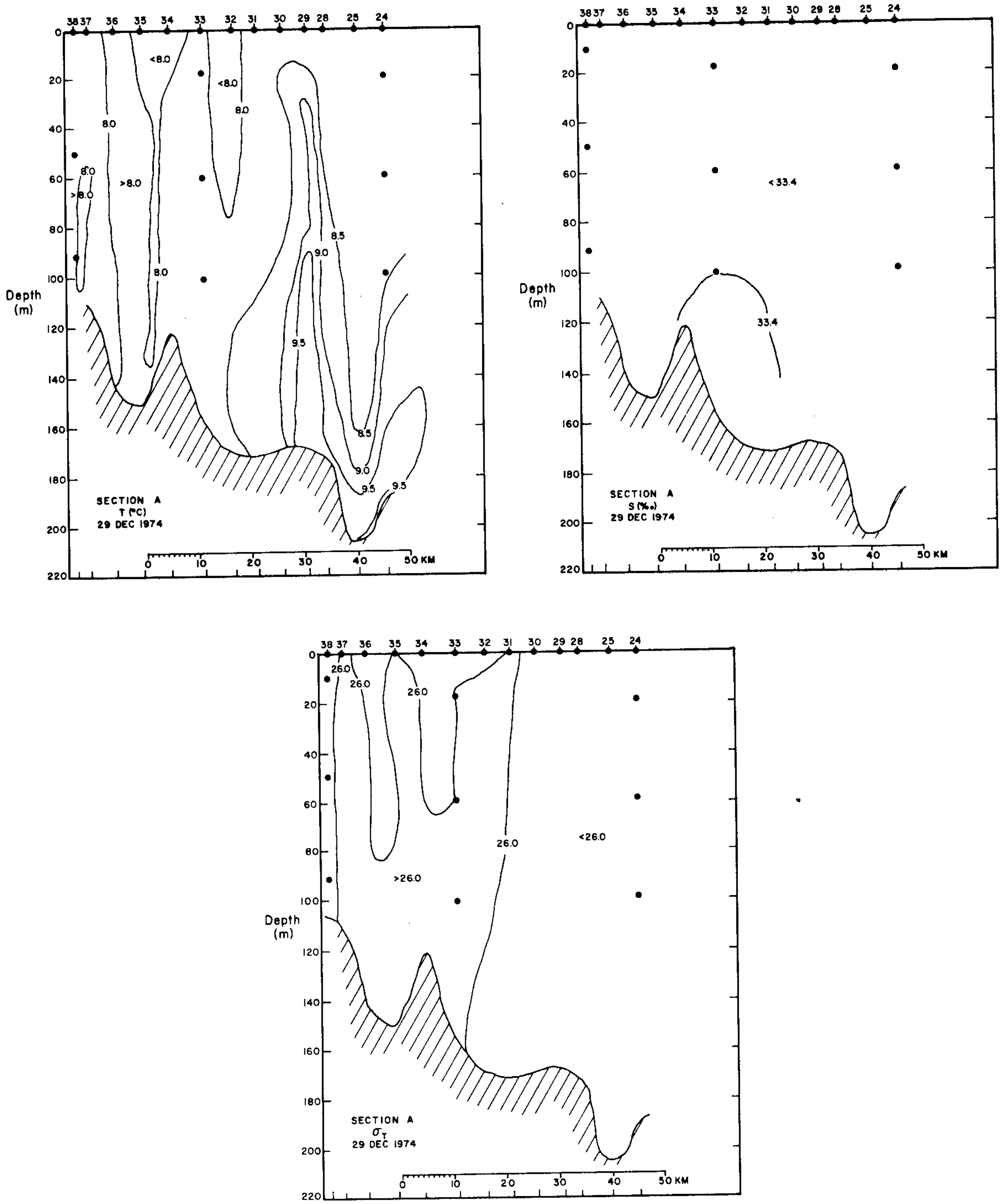


Figure 28. Track A temperature, salinity and sigma-t sections, which were made during the inshore leg of Cruise 12; 29 December 1974. The salinity (sigma-t) stations are indicated by (●).

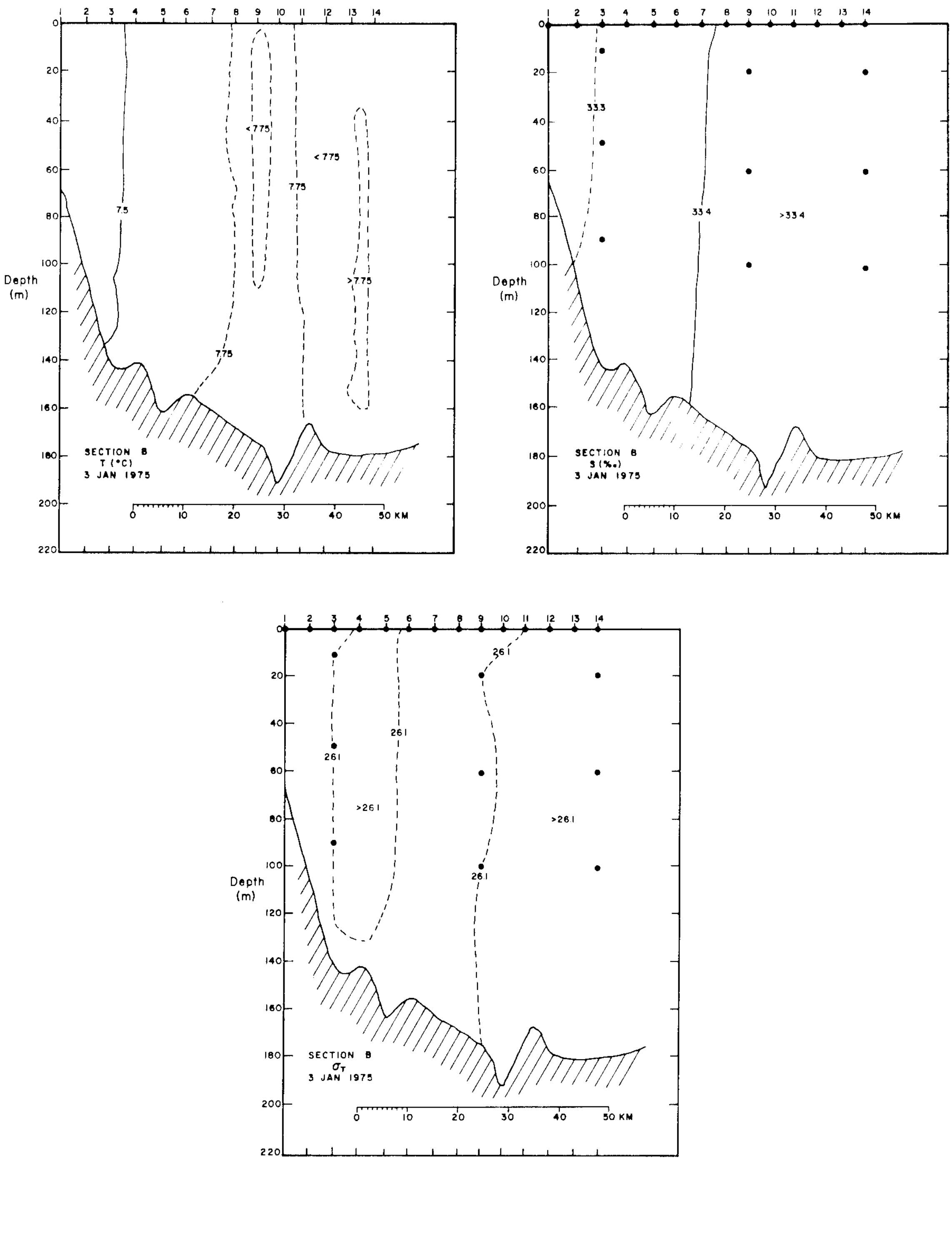


Figure 29. Track B temperature, salinity, and sigma-t sections, which were made during the offshore leg of Cruise 14; 3 January 1975. The salinity (sigma-t) stations are indicated by (●).

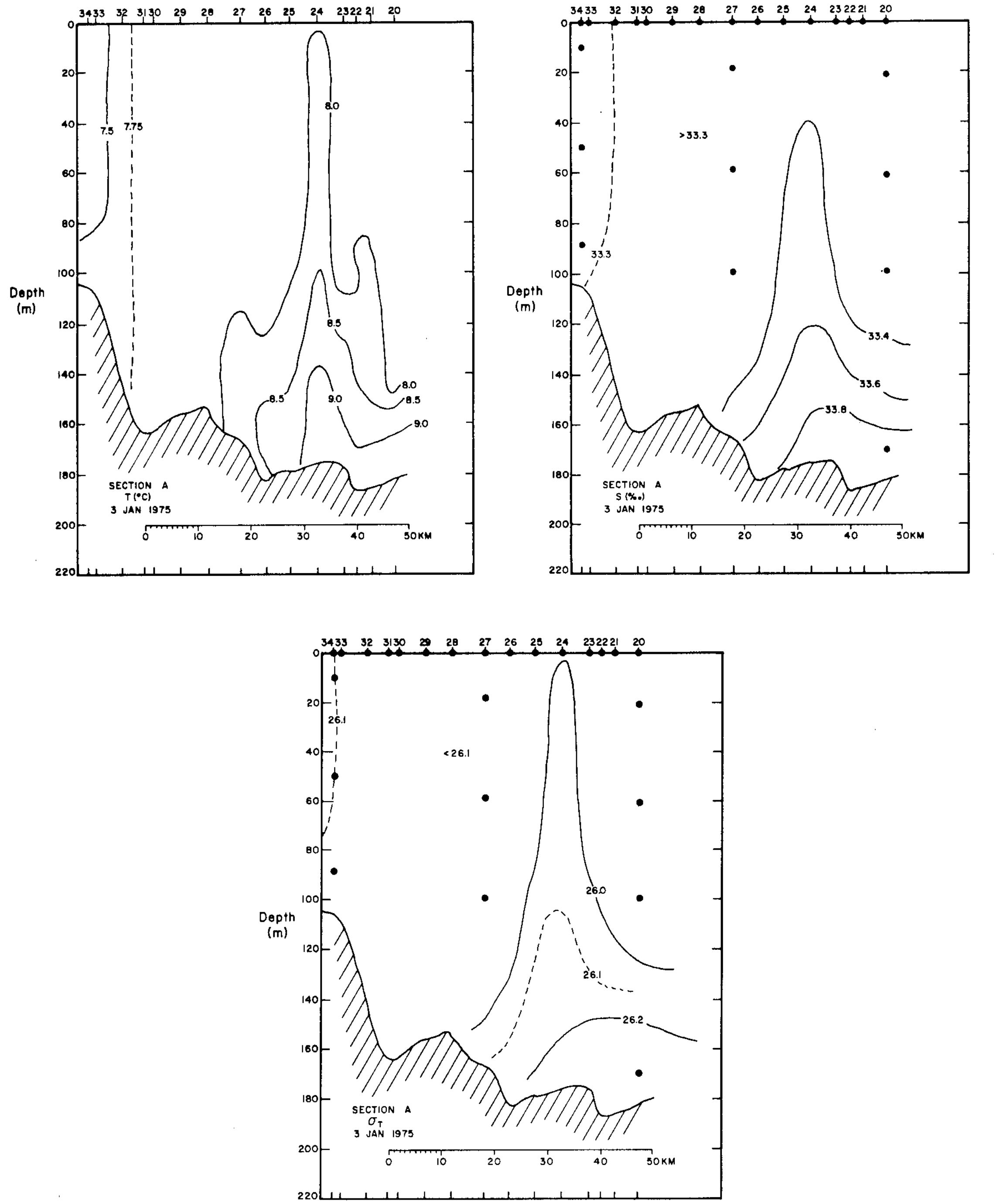


Figure 30. Track A temperature, salinity, and sigma-t sections, which were made during the inshore leg of Cruise 14; 3 January 1975. The salinity (sigma-t) stations are indicated by (●).

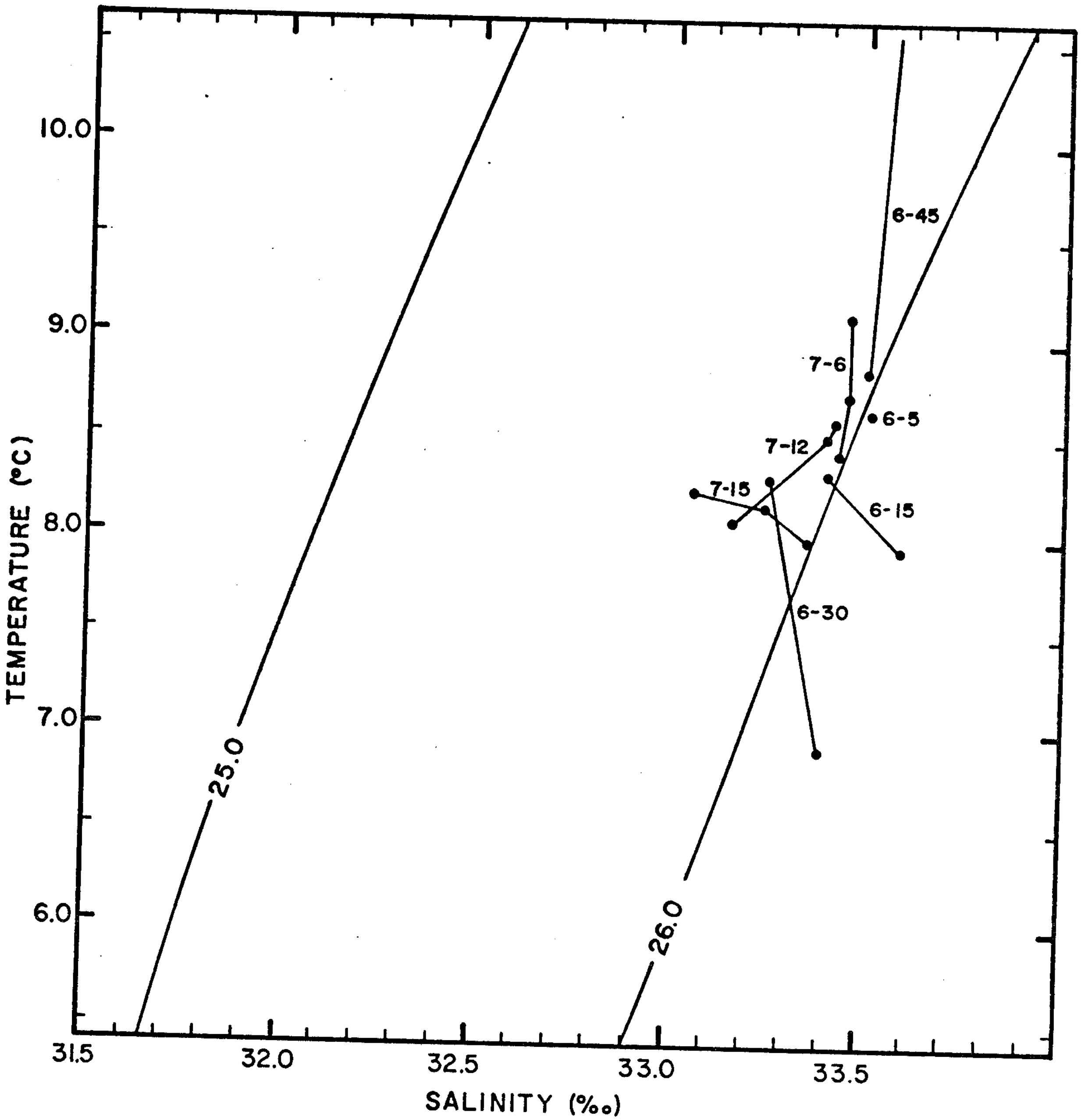


Figure 31. T-S presentation of hydrographic data from the Cruises 6 and 7; 5 and 6 December 1974. Each profile is identified with an appropriate number, which contains the cruise number followed by the station number.

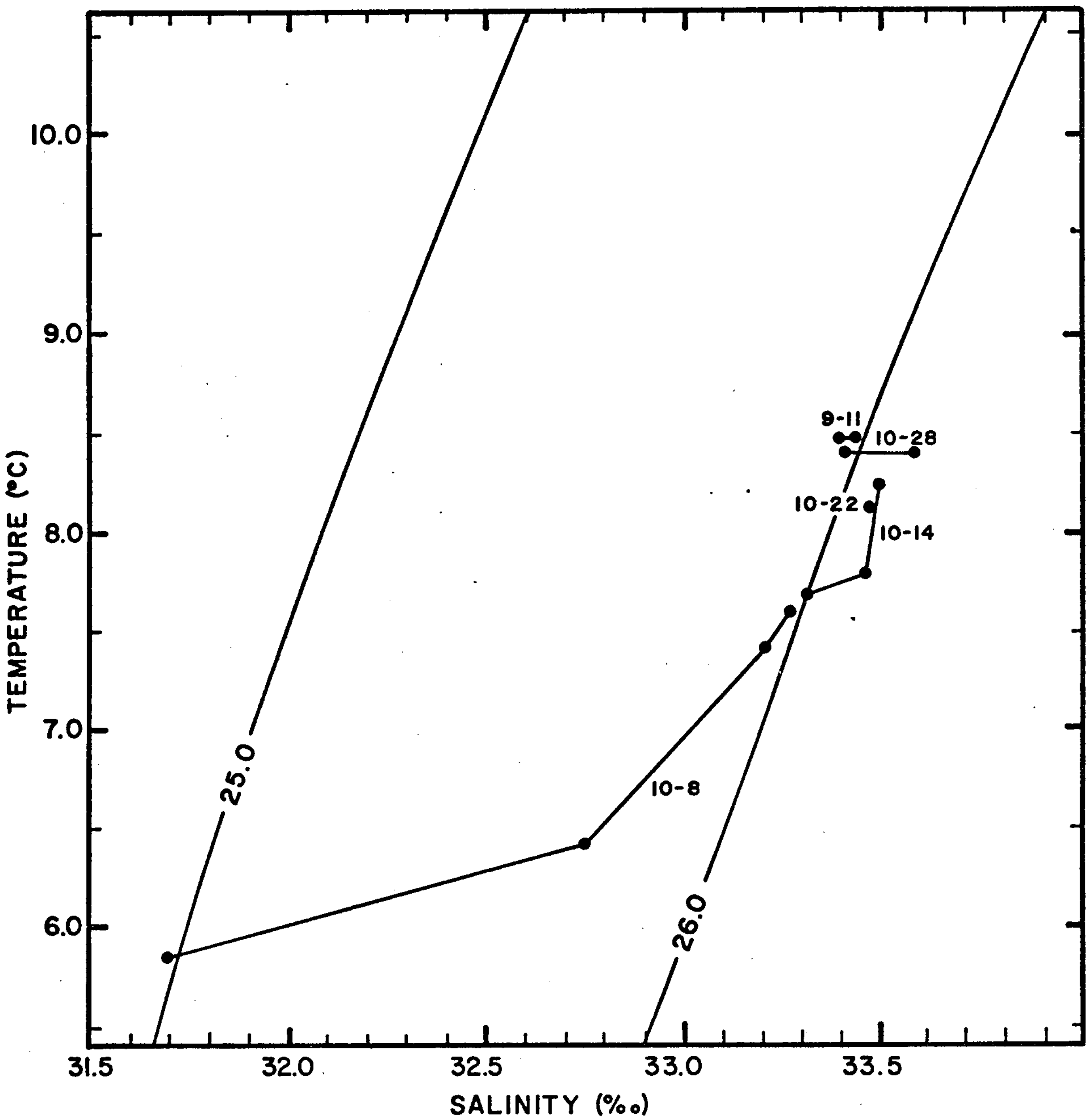


Figure 32. T-S presentation of hydrographic data from Cruises 9 and 10; 18 and 20 December 1974. Each profile is identified with an appropriate number, which contains the cruise number followed by the station number.

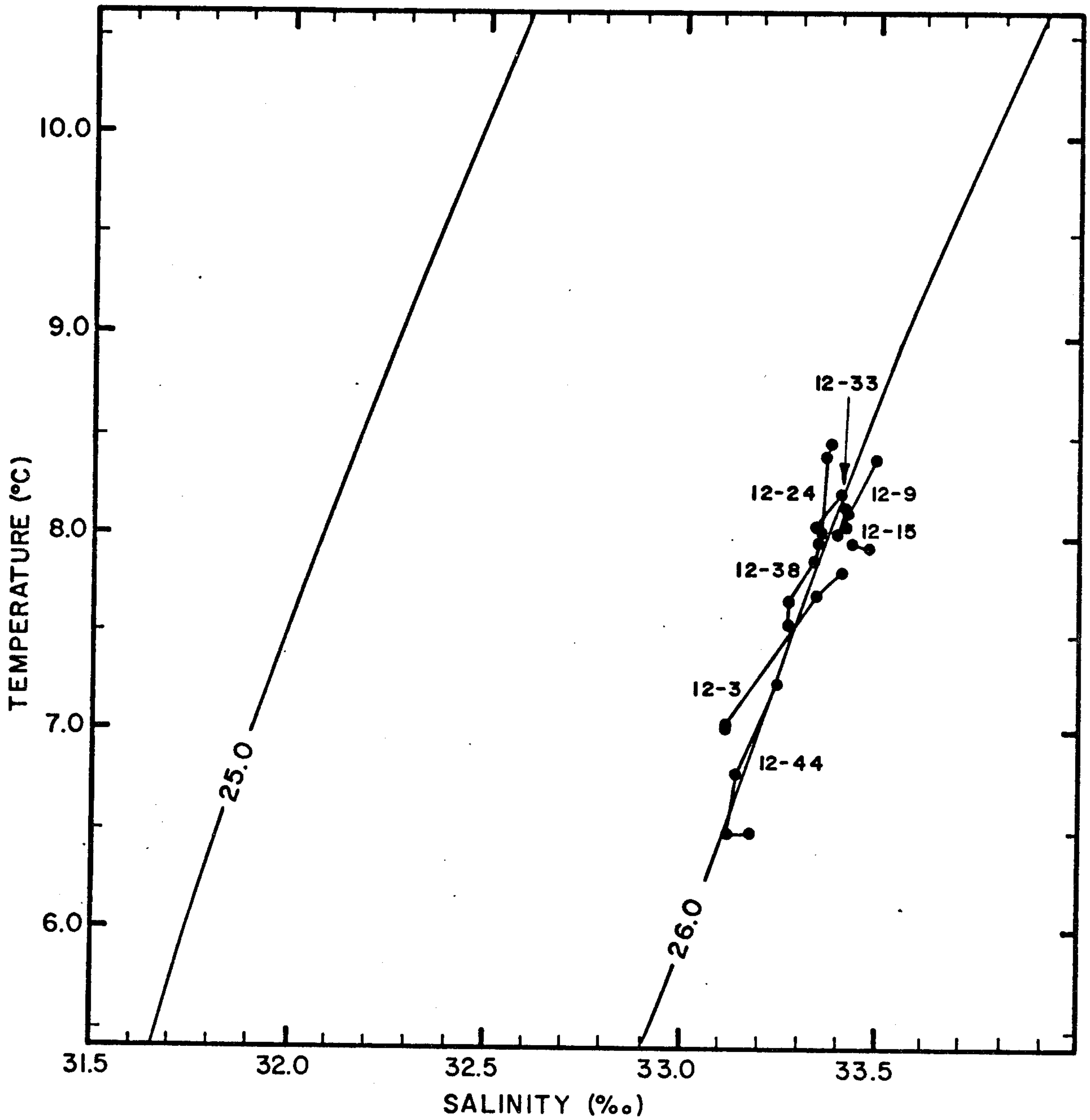


Figure 33. T-S presentation of hydrographic data from Cruise 12; 29 December 1974. Each profile is identified by its appropriate station number.

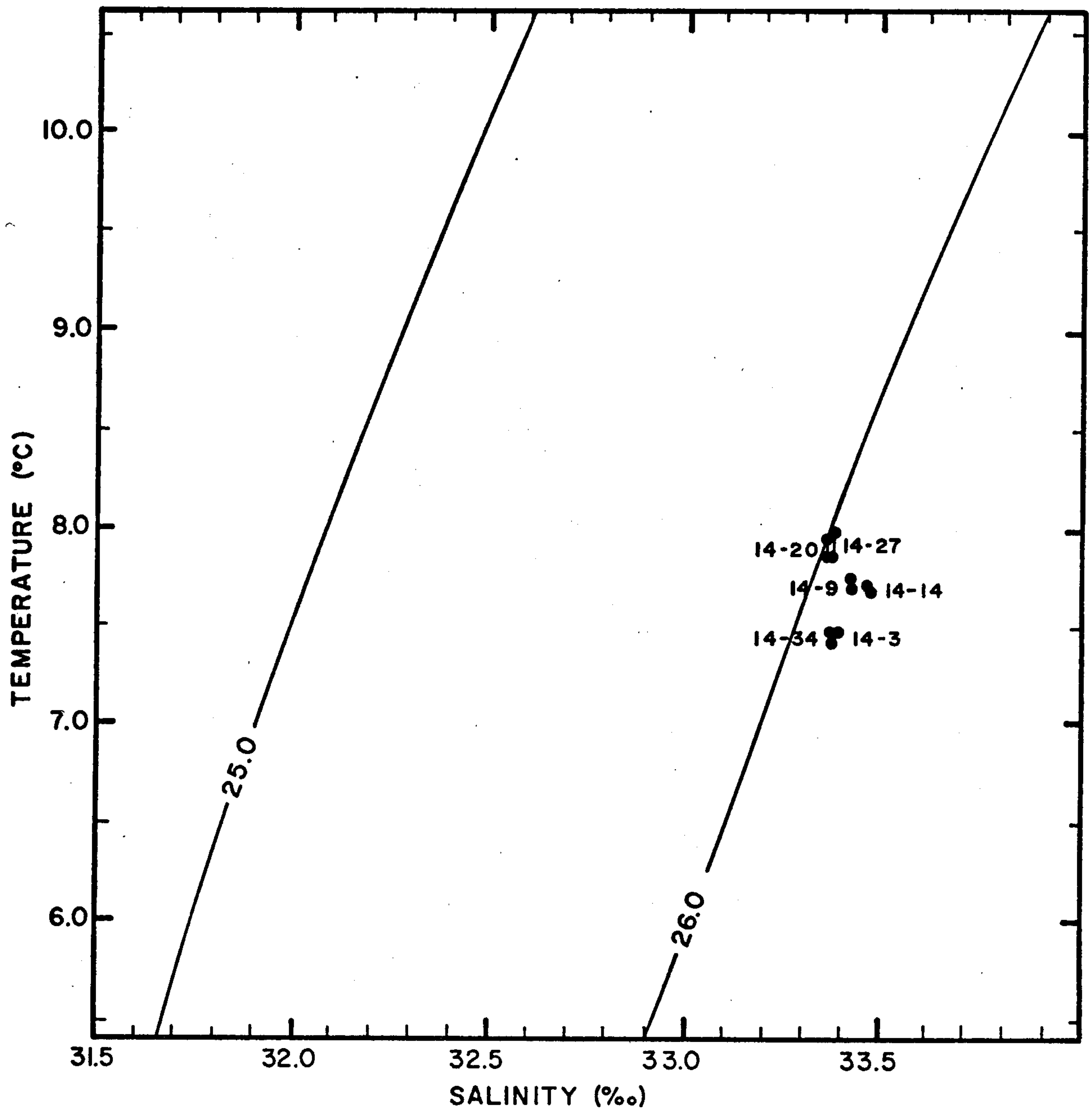


Figure 34. T-S presentation of hydrographic data from Cruise 14; 3 January 1975. Each profile is identified by its appropriate station number.

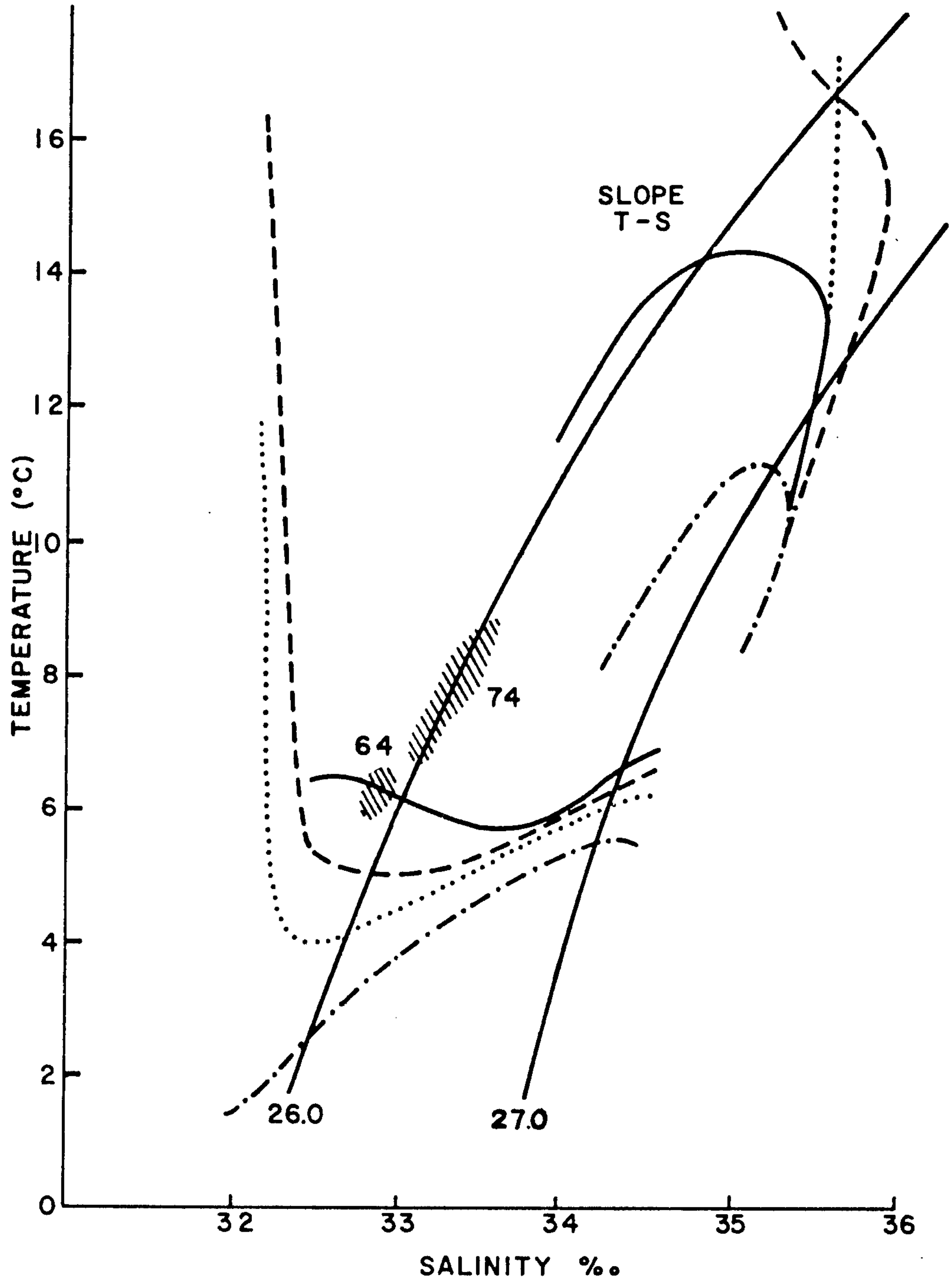


Figure 35. Typical Seasonal Variations in the Gulf of Maine T-S Relationship.

A T-S curve for December ( ), March (,), May (····), and September (----) is shown for both the Gulf of Maine to the left and for the SLOPE WATER to the right. The hatched areas represent the location of measurements made in the study area during 1974 experiment and 1964 by Colton et al (1968).

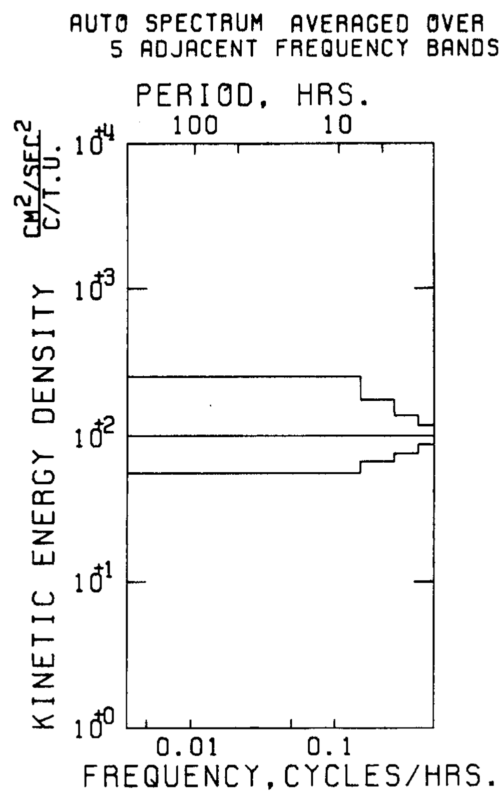


Figure 36. Ninety percent confidence intervals for the logarithmically band-averaged spectra.

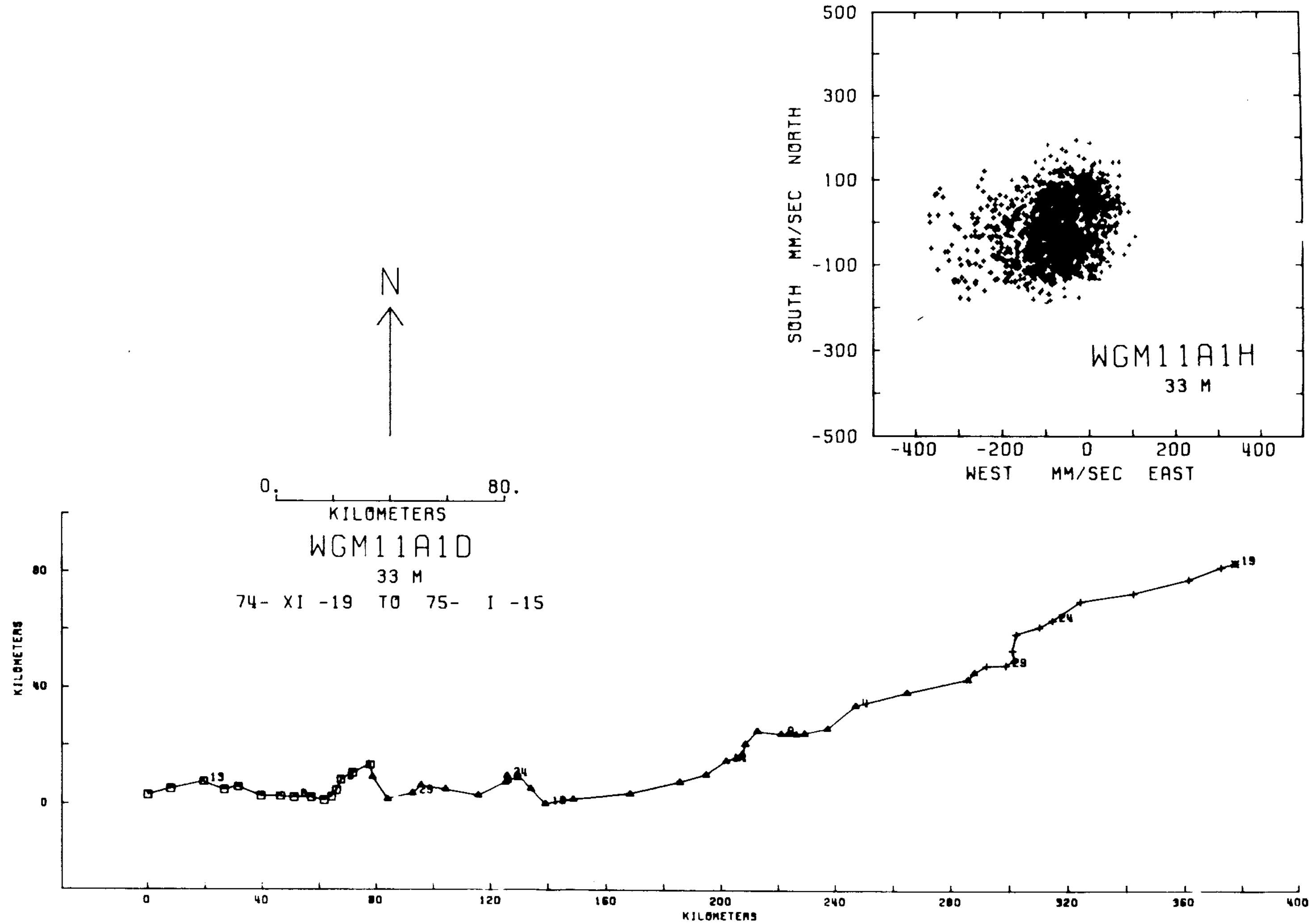


Figure 37. Progressive vector diagram of daily-averaged data and scatter plot of hourly-averaged data for instrument record WGM 11.

VARIABLE	EAST	NORTH	SPEED	TEMPERATURE
UNITS	MM/S	MM/S	MM/S	DEGREES C.
MEAN	-76.627	-16.417	114.298	7.840
STD. ERR.	2.090	1.908	1.709	.233E-1
VARIANCE	5943.482	4953.558	3974.218	.738
STD. DEV.	77.094	70.382	63.041	.859
KURTOSIS	4.046	2.333	5.015	3.384
SKEWNESS	-.794	.743E-1	1.244	-.799
MINIMUM	-366.833	-192.269	4.041	5.343
MAXIMUM	104.408	190.897	368.034	9.248

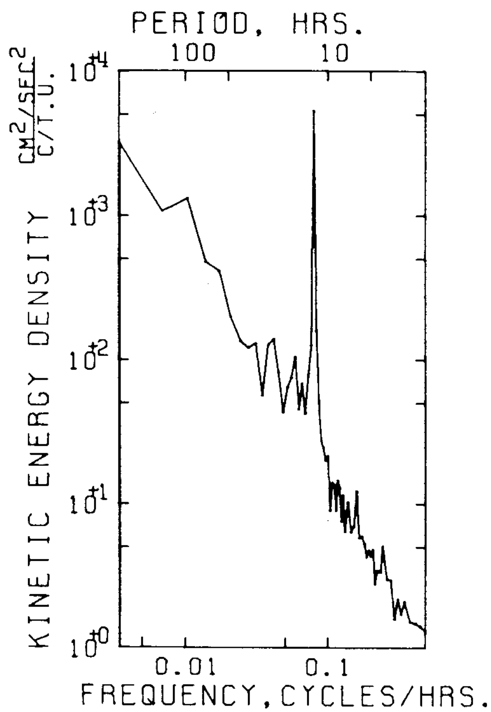
EAST & NORTH	
COVARIANCE	1218.620
STD. ERR. OF COVARIANCE	218.329
STD. DEV. OF COVARIANCE	8054.539
CORRELATION COEFFICIENT	.225
VECTOR MEAN	78.366
VECTOR VARIANCE	5448.520
VECTOR STD. DEV.	73.814

SAMPLE SIZE = 1361 POINTS

SPANNING RANGE
FROM 74- XI -20 01.07.30
TO 75- I -15 17.07.30

DURATION 56.67 DAYS

AUTO SPECTRUM
WGM11A1H EAST
WGM11A1H NORTH
33 METERS
74-XI-20 TO 75-I-19
1 PIECES WITH 720 ESTIMATES
PER PIECE. AVERAGED OVER
5 ADJACENT FREQUENCY BANDS
14:12 MAR 07,'77



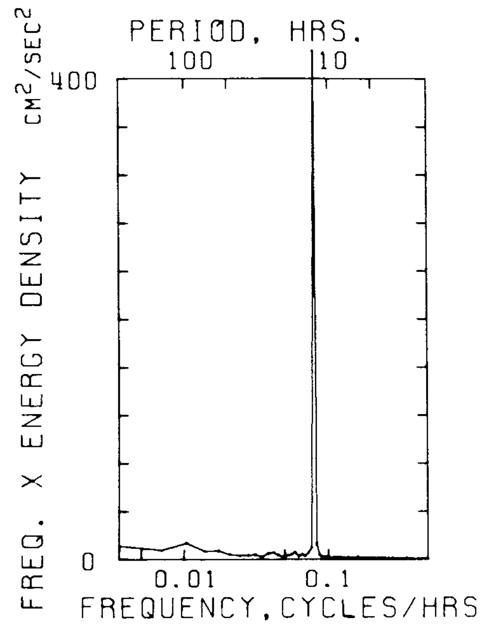


Figure 38. Statistics and spectra computed from hourly-averaged data for instrument record WGM 11.

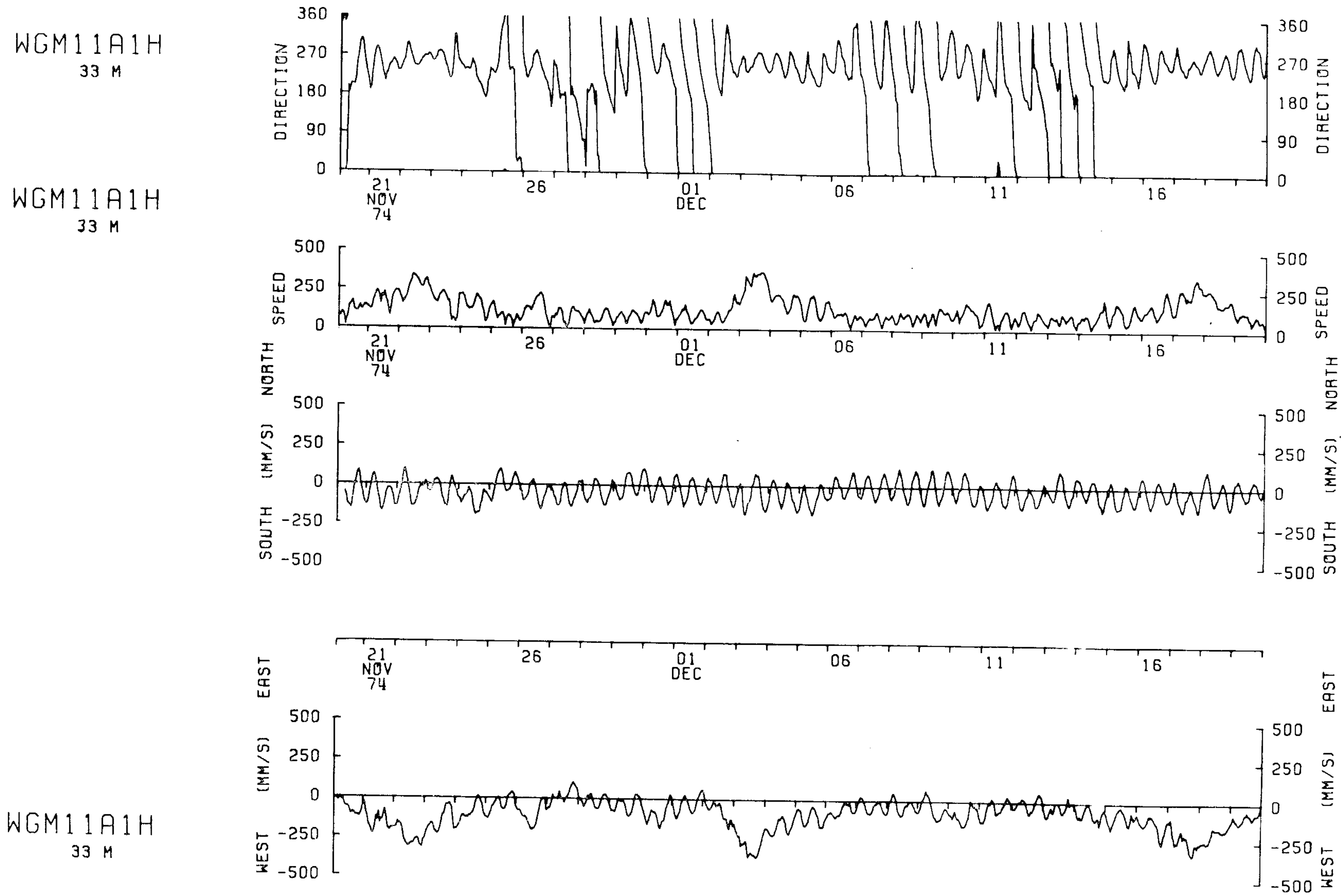


Figure 39. Time series of hourly-averaged data for instrument record WGM 11 (first half).

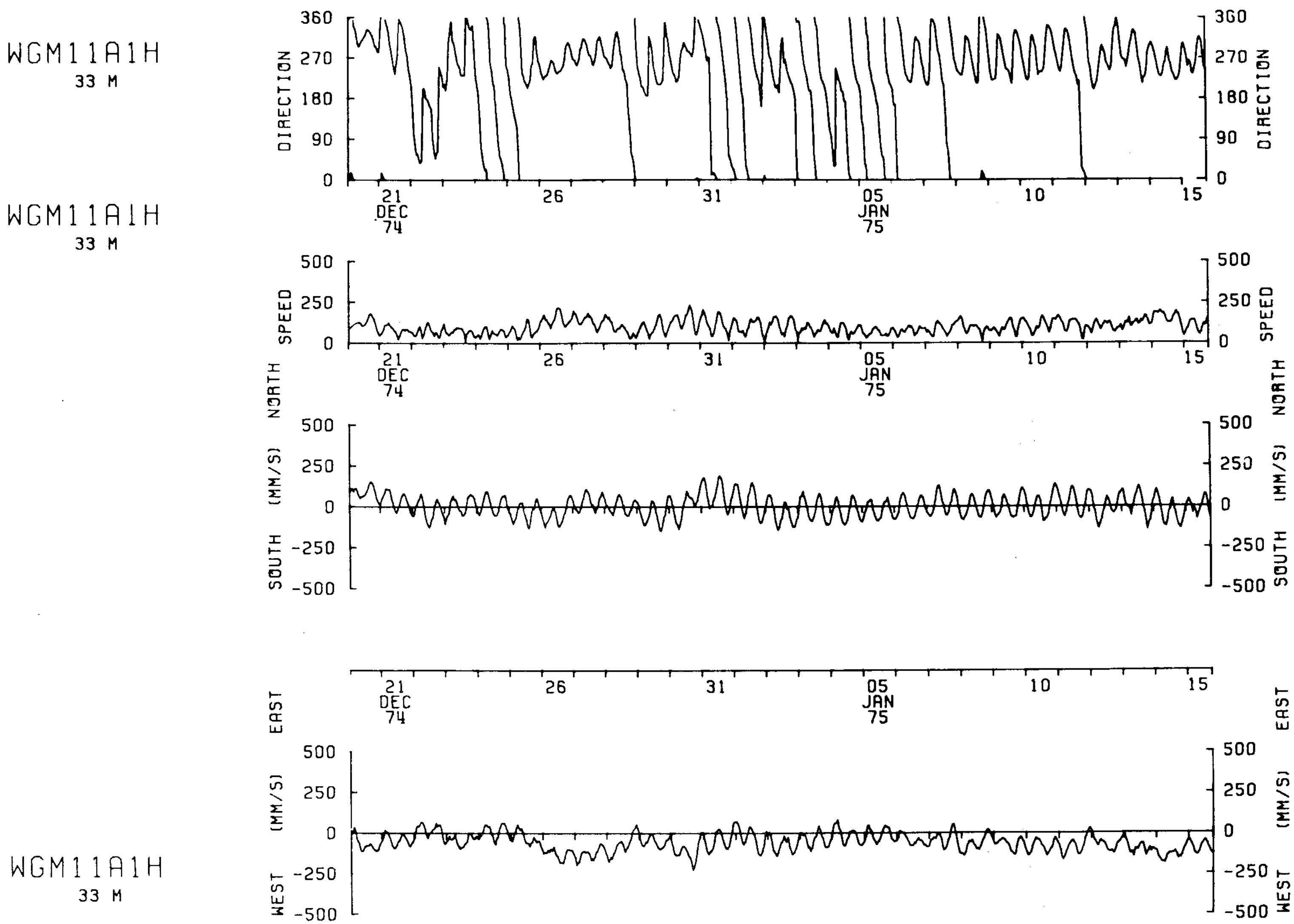


Figure 40. Time series of hourly-averaged data for instrument record WGM 11 (second half).

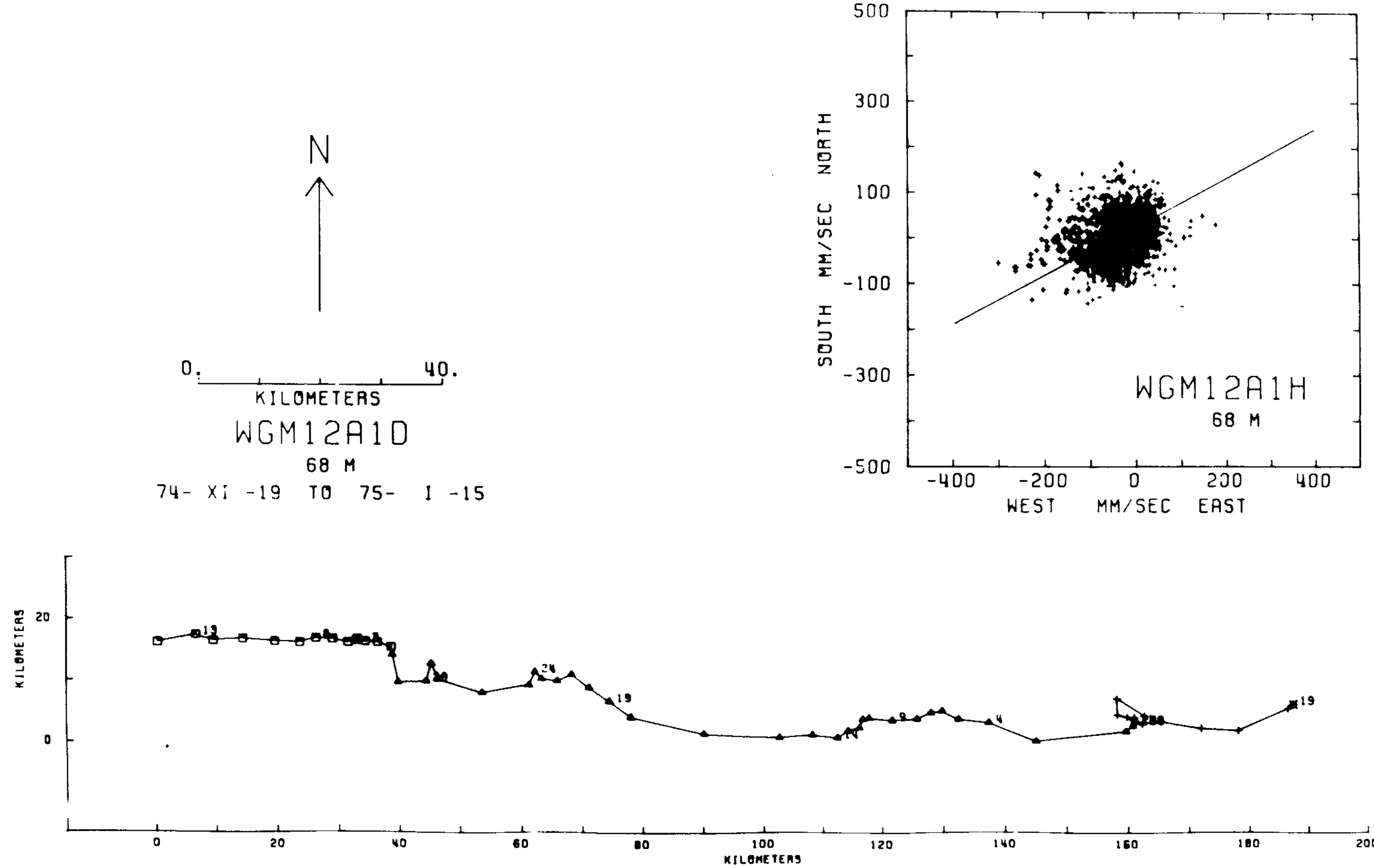


Figure 41. Progressive vector diagram of daily-averaged data and scatter plot of hourly-averaged data for instrument record WGM 12.

VARIABLE	EAST COMP	NORTH COMP	SPEED
UNITS	MM/SEC	MM/SEC	MM/SEC
MEAN	-39.010	2.199	72.289
STD. ERR.	1.537	1.342	1.202
VARIANCE	3217.022	2449.867	1967.863
STD. DEV.	56.719	49.496	44.361
KURTOSIS	4.360	2.852	5.629
SKEWNESS	-.732	.831E-1	1.357
MINIMUM	-302.132	-152.347	1.552
MAXIMUM	174.466	162.563	307.075

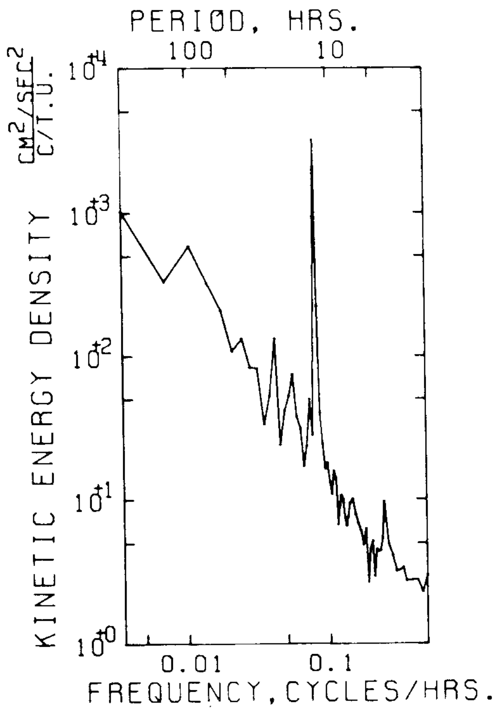
EAST COMP & NORTH COMP	
COVARIANCE	574.999
STD. ERR. OF COVARIANCE	104.394
STD. DEV. OF COVARIANCE	3851.258
CORRELATION COEFFICIENT	.205
VECTOR MEAN	39.072
VECTOR VARIANCE	2833.445
VECTOR STD. DEV.	53.230

SAMPLE SIZE = 1361 POINTS

SPANNING RANGE
FROM 74- XI -20 00.55.00
TO 75- I -15 16.55.00

DURATION 56.67 DAYS

AUTO SPECTRUM
WGM12A1H EAST COMP
WGM12A1H NORTH COMP
68 METERS
74-XI-20 TO 75-I-18
1 PIECES WITH 720 ESTIMATES
PER PIECE. AVERAGED OVER
5 ADJACENT FREQUENCY BANDS
07.15 MAR 08,'77



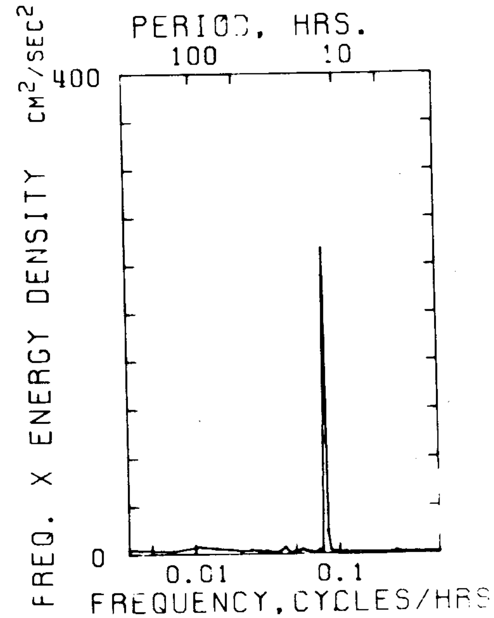


Figure 42. Statistics and spectra computed from hourly-averaged data for instrument record WGM 12.

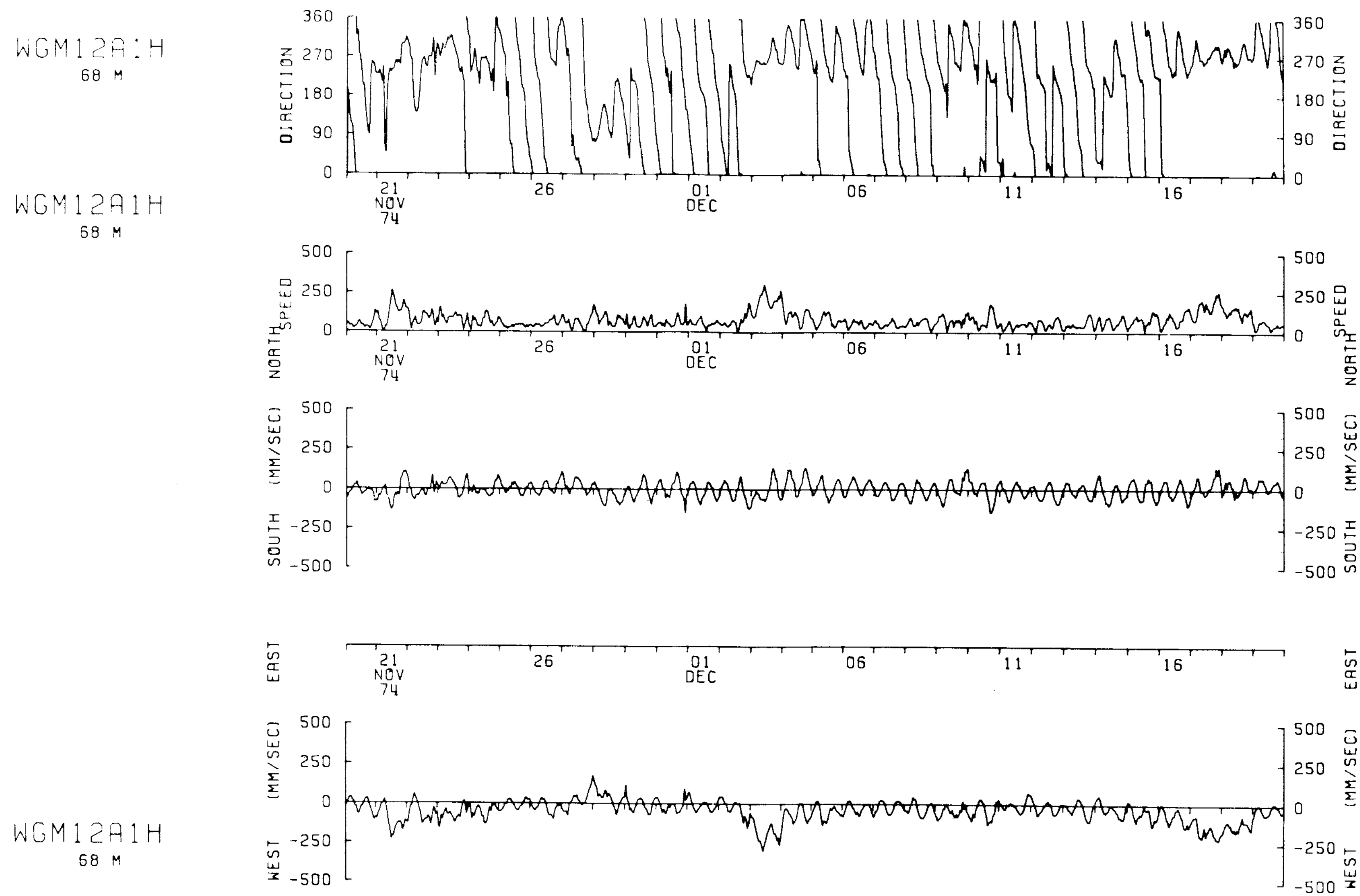


Figure 43. Time series of hourly-averaged data for instrument record WGM 12 (first half).

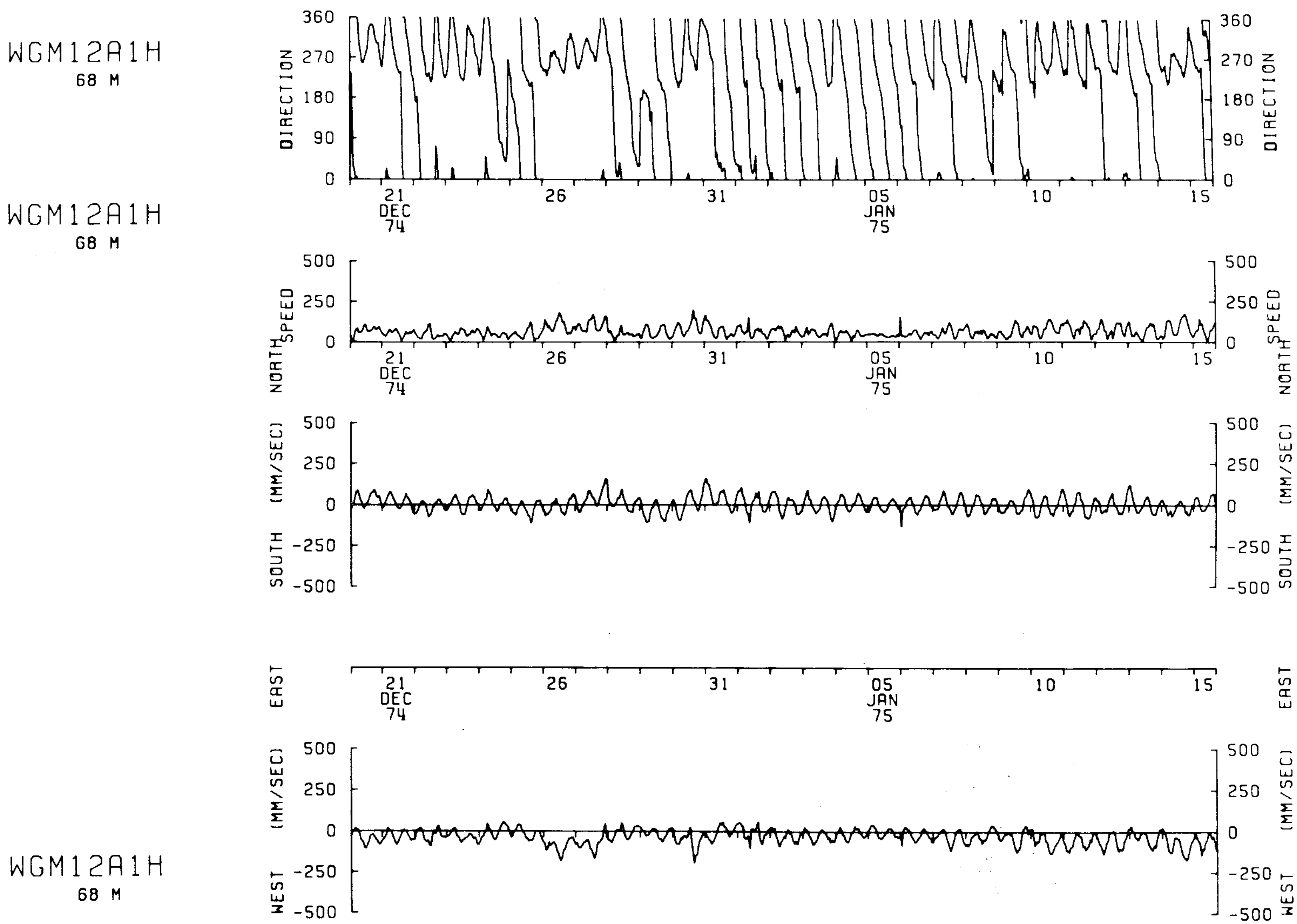


Figure 44. Time series of hourly-averaged data for instrument record WGM 12 (second half).

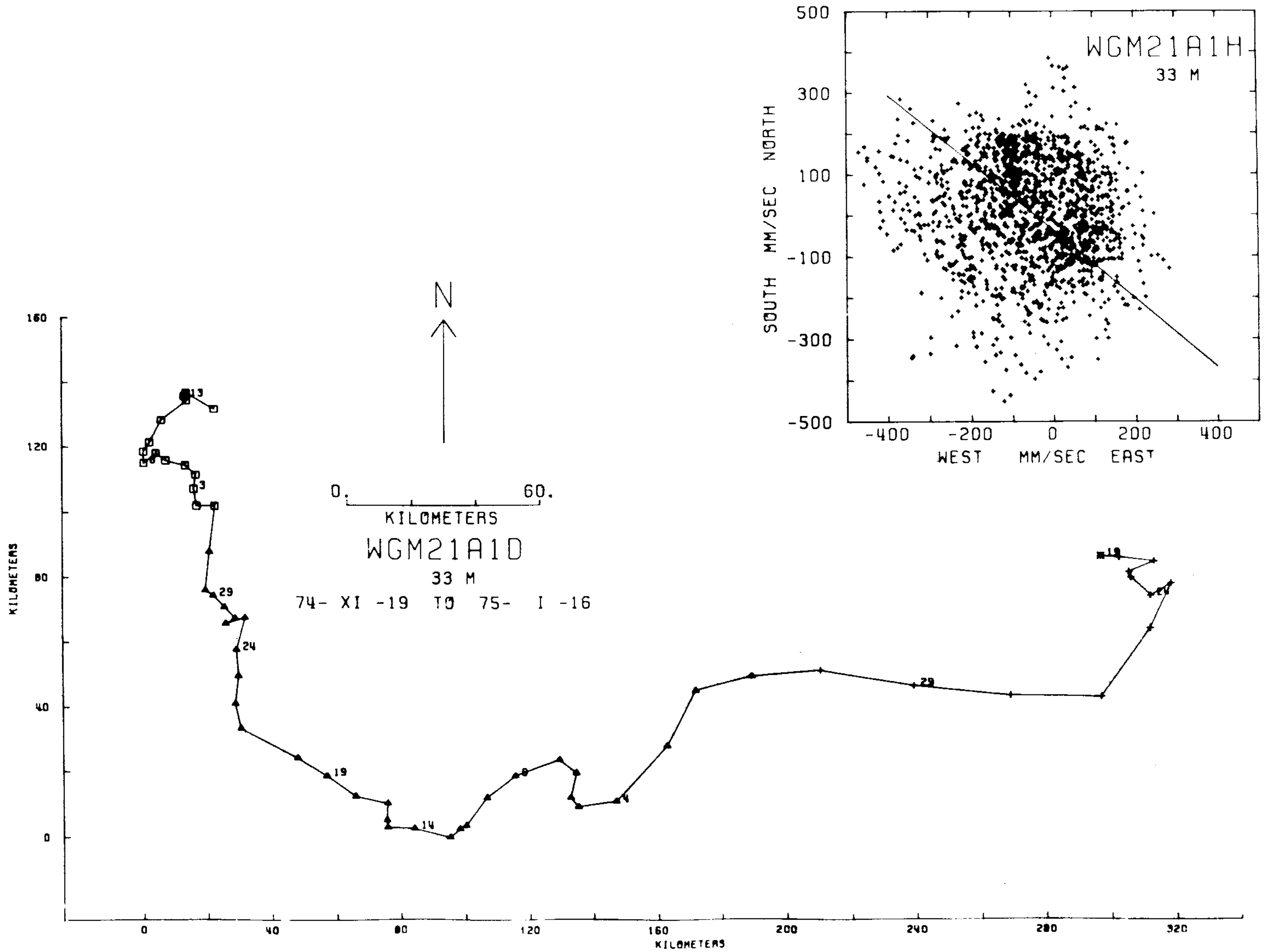


Figure 45. Progressive vector diagram of daily-averaged data and scatter plot of hourly-averaged data for instrument record WGM 21.

VARIABLE		EAST	NORTH	SPEED	TEMPERATURE
UNITS		MM/S	MM/S	MM/S	DEGREES C.
MEAN	=	-56.574	10.015	175.968	8.362
STD. ERR.	=	3.659	3.595	2.446	.138E-1
VARIANCE	=	18223.176	17585.795	8145.174	.260
STD. DEV.	=	134.993	132.611	90.251	.510
KURTOSIS	=	2.822	3.053	3.519	1.890
SKEWNESS	=	-.376	-.380	.819	.194
MINIMUM	=	-470.591	-450.811	1.828	7.483
MAXIMUM	=	283.227	384.006	495.425	9.443

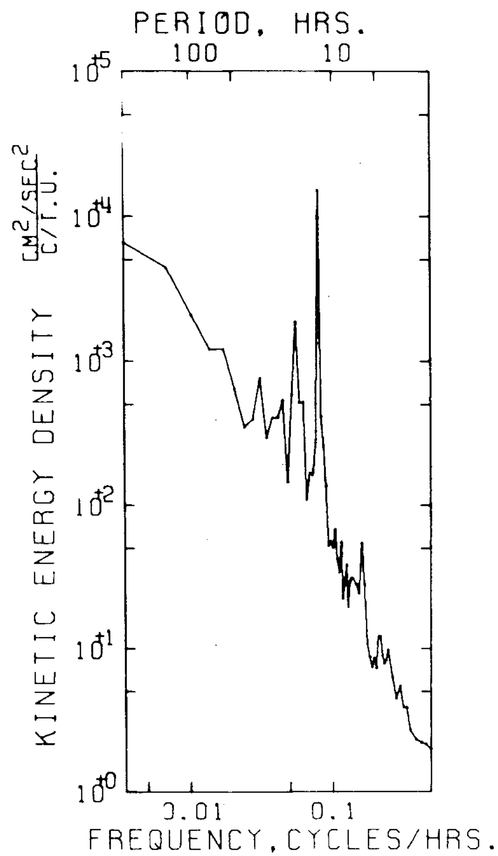
EAST & NORTH		
COVARIANCE	=	-1495.008
STD. ERR. OF COVARIANCE	=	505.269
STD. DEV. OF COVARIANCE	=	18640.260
CORRELATION COEFFICIENT	=	-.835E-1
VECTOR MEAN	=	57.454
VECTOR VARIANCE	=	17904.485
VECTOR STD. DEV.	=	133.808

SAMPLE SIZE = 1361 POINTS

SPANNING RANGE
FROM 74- XI -20 01.07.30
TO 75- I -15 17.07.30

DURATION 56.67 DAYS

AUTO SPECTRUM
WGM21A1H EAST
WGM21A1H NORTH
33 METERS
74-XI-20 TO 75-I-19
1 PIECES WITH 720 ESTIMATES
PER PIECE. AVERAGED OVER
5 ADJACENT FREQUENCY BANDS
14:12 MAR 07.'77



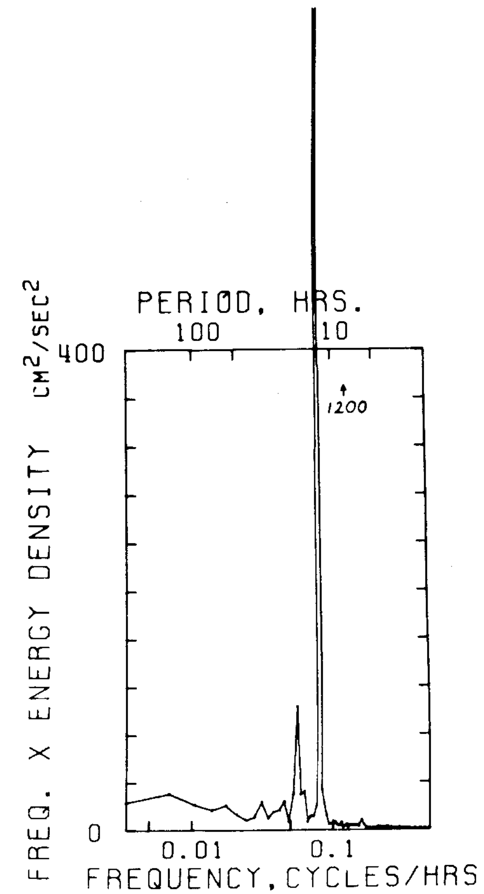


Figure 46. Statistics and spectra computed from hourly-averaged data for instrument record WGM 21.

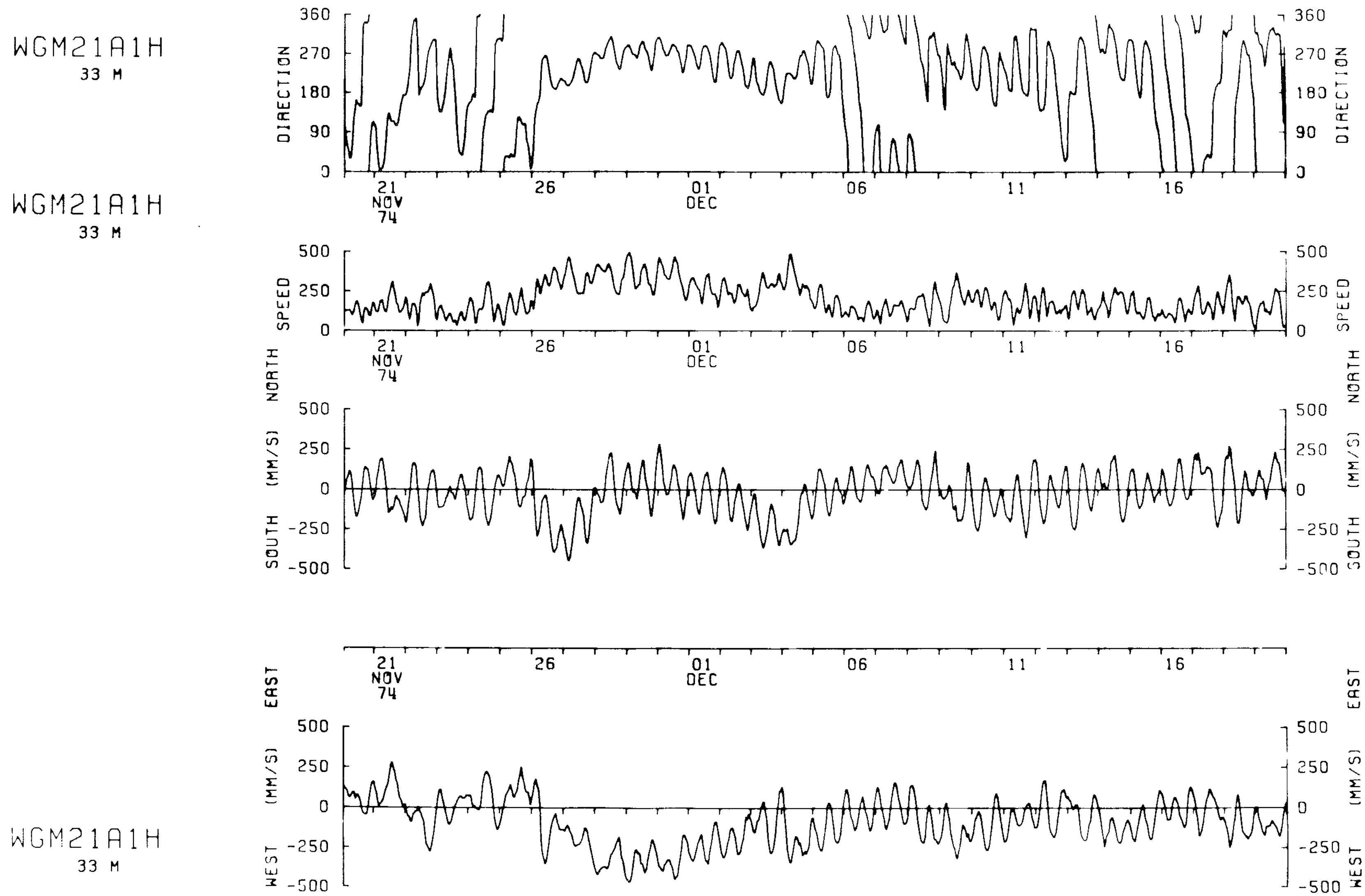


Figure 47. Time series of hourly-averaged data for instrument record WGM 21 (first half).

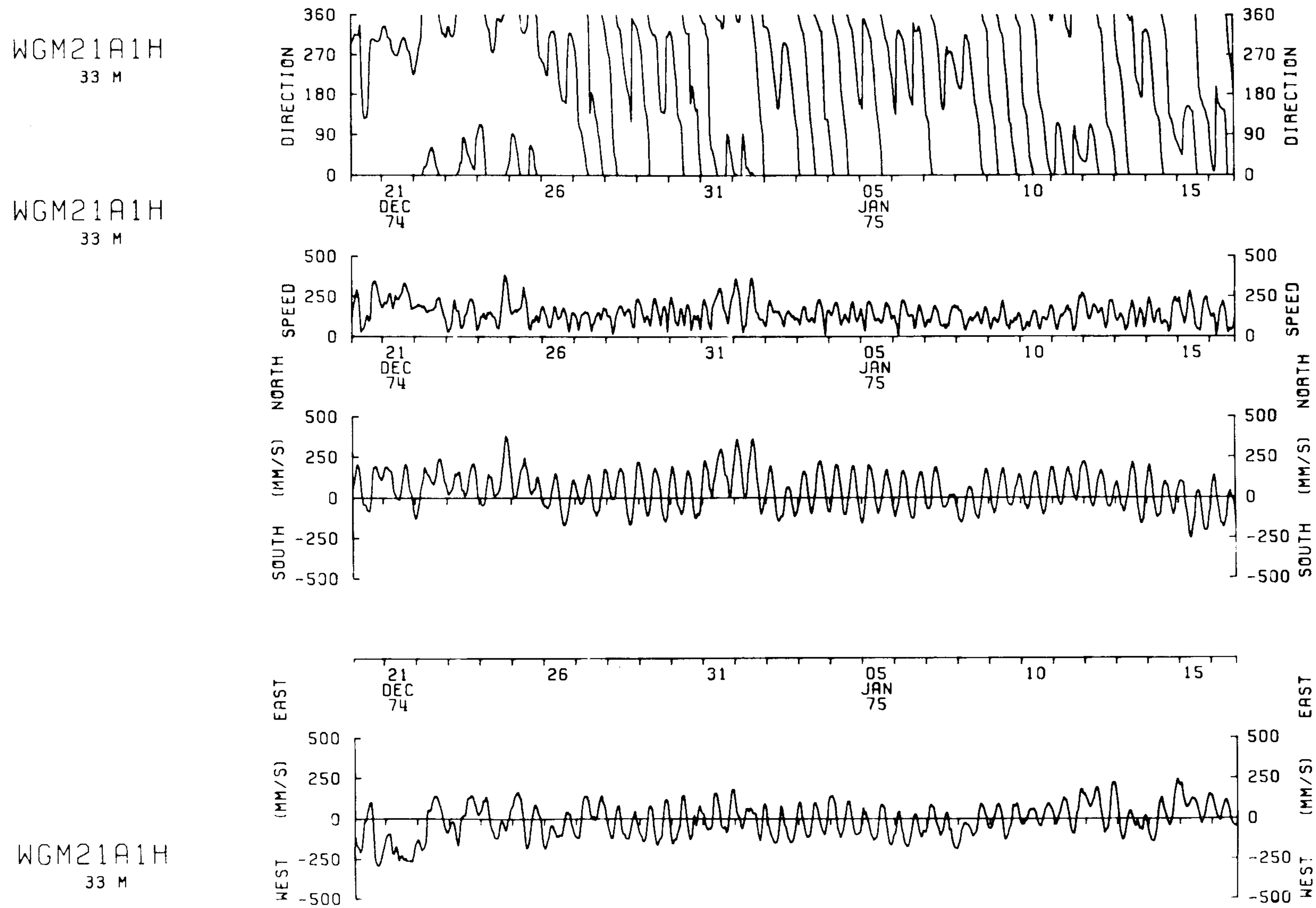


Figure 48. Time series of hourly-averaged data for instrument record WGM 21 (second half).

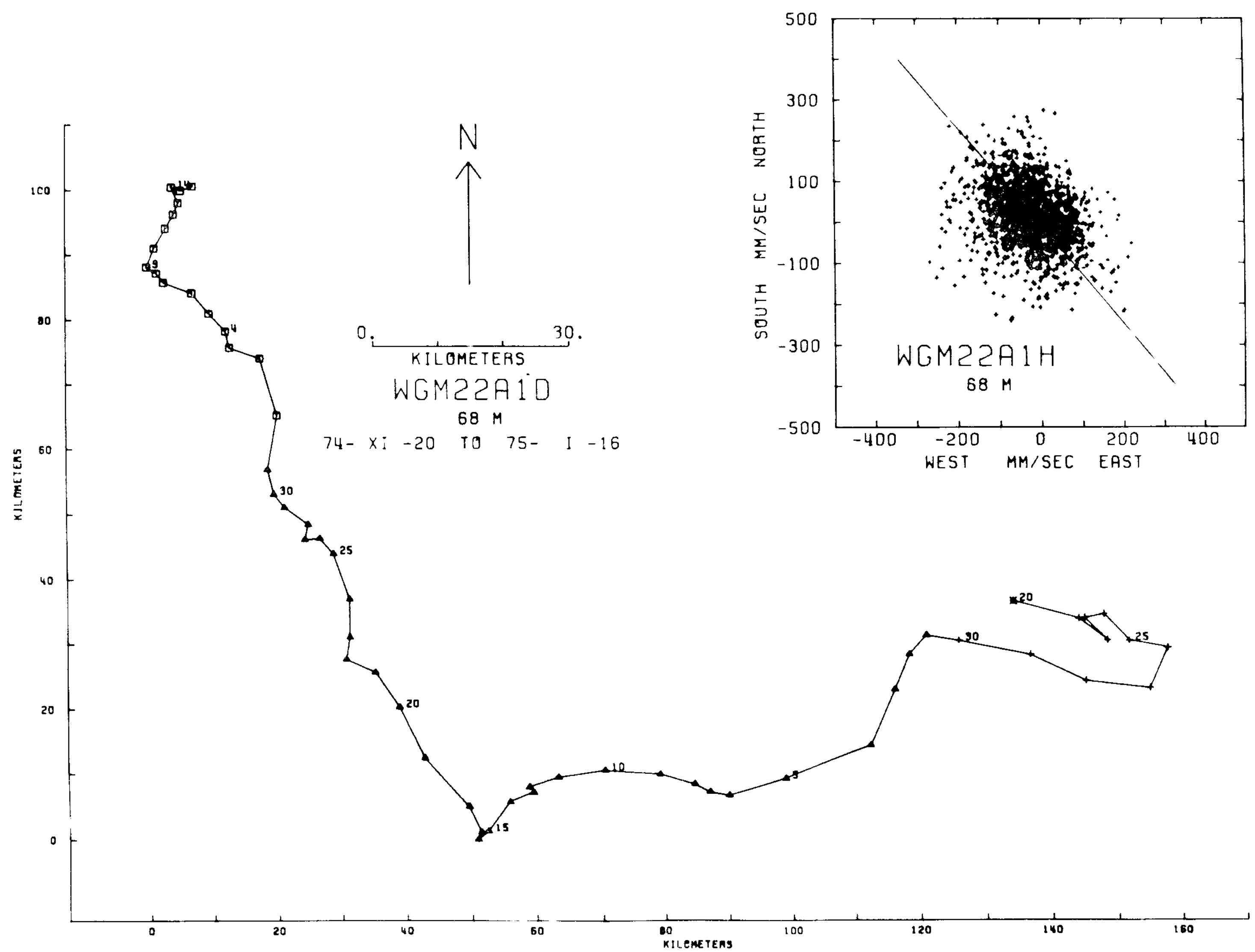


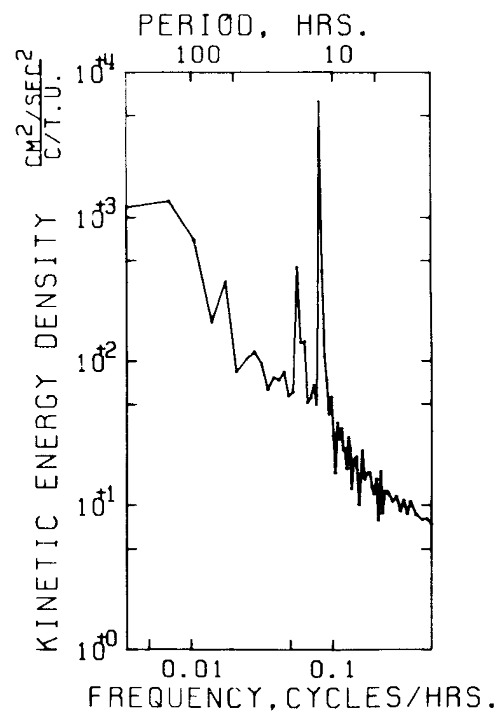
Figure 49. Progressive vector diagram of daily-averaged data and scatter plot of hourly-averaged data for instrument record WGM 22.

VARIABLE *	EAST COMP	NORTH COMP	SPEED
UNITS *	MM/SEC	MM/SEC	MM/SEC
MEAN =	-25.872	12.986	96.103
STD. ERR. =	2.011	2.119	1.538
VARIANCE =	5504.513	6112.189	3218.964
STD. DEV. =	74.192	78.180	56.736
KURTOSIS =	3.264	3.314	3.428
SKEWNESS =	-.138	.332E-1	.838
MINIMUM =	-271.381	-239.352	1.801
MAXIMUM =	217.691	272.125	320.522

EAST COMP & NORTH COMP		
COVARIANCE	=	-1648.721
STD. ERR. OF COVARIANCE	=	183.872
STD. DEV. OF COVARIANCE	=	6783.355
CORRELATION COEFFICIENT	=	-.284
VECTOR MEAN	=	28.948
VECTOR VARIANCE	=	5808.351
VECTOR STD. DEV.	=	76.213

* SAMPLE SIZE = 1361 POINTS
*
* SPANNING RANGE
* FROM 74- XI -20 00.55.00
* TO 75- I -15 16.55.00
*
* DURATION 56.67 DAYS

AUTO SPECTRUM
WGM22A1H EAST COMP
WGM22A1H NORTH COMP
68 METERS
74-XI-20 TO 75-I-18
1 PIECES WITH 720 ESTIMATES
PER PIECE. AVERAGED OVER
5 ADJACENT FREQUENCY BANDS
07:20 MAR 08.'77



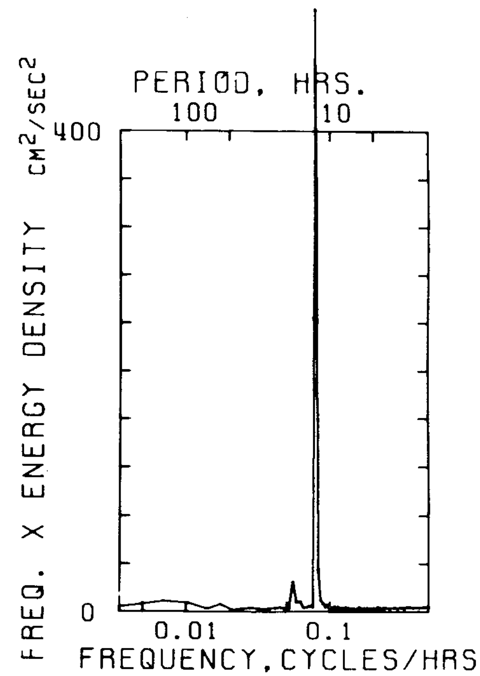


Figure 50. Statistics and spectra computed from hourly-averaged data for instrument record WGM 22.

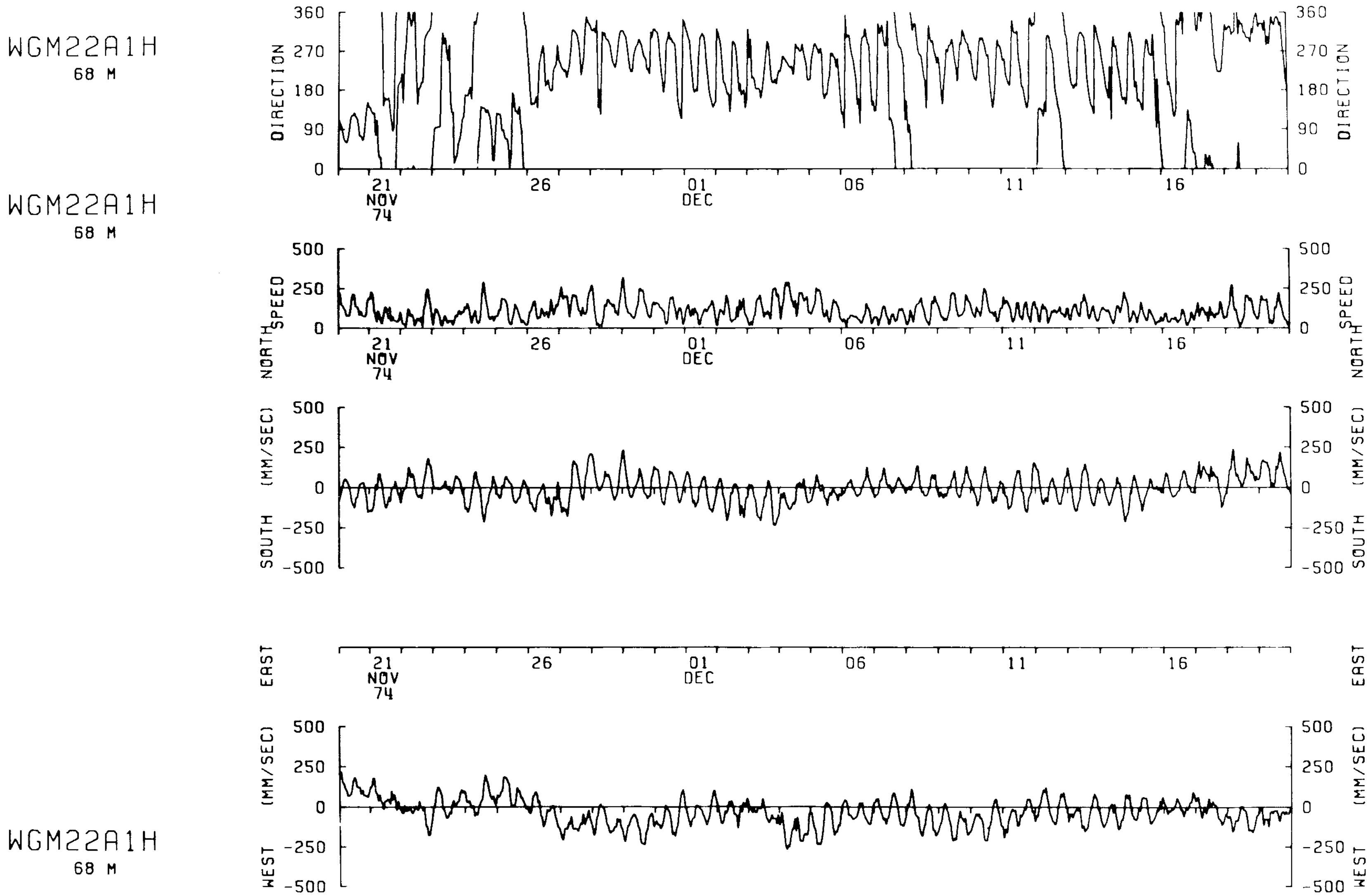


Figure 51. Time series of hourly-averaged data for instrument record WGM 22 (first half).

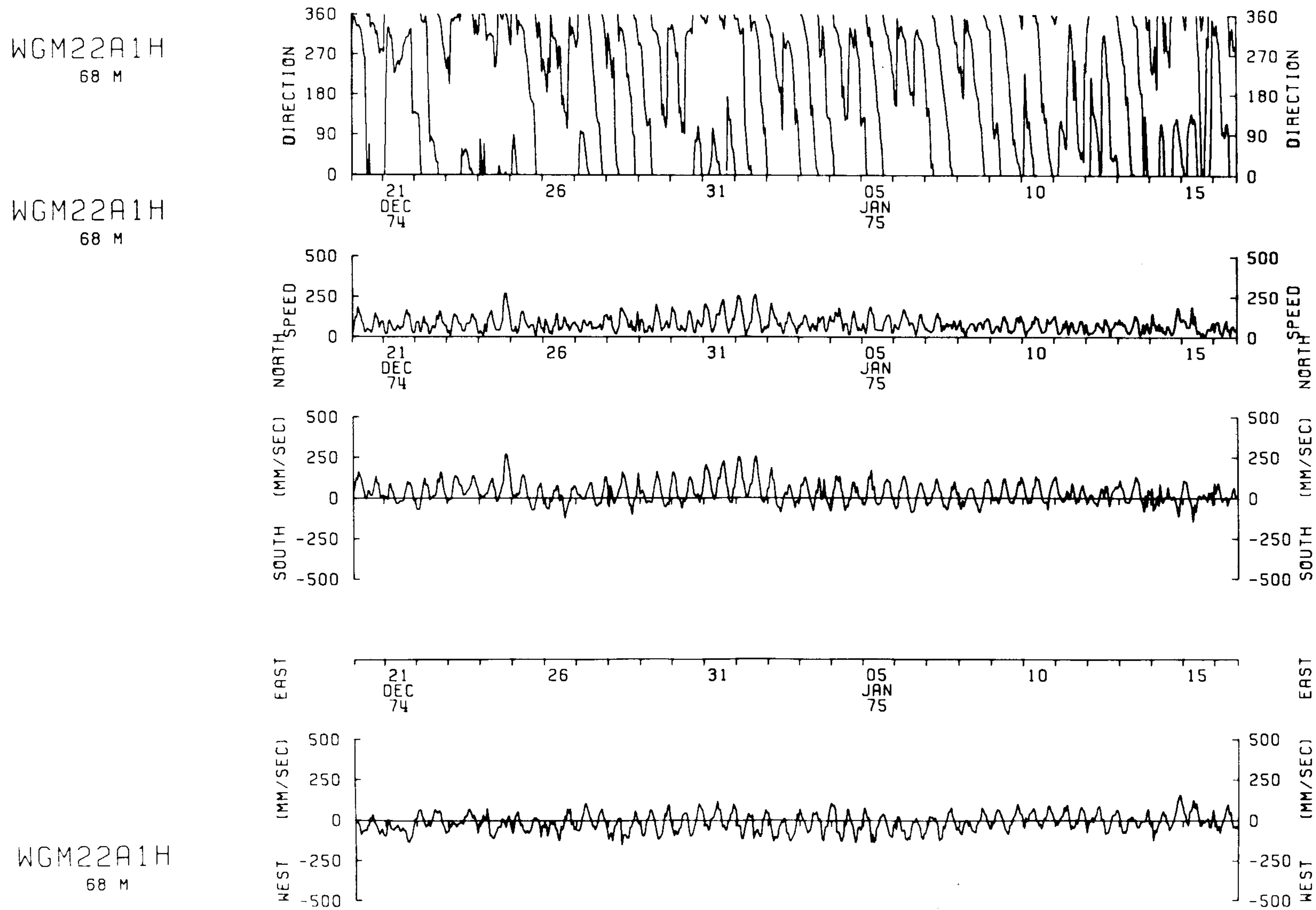


Figure 52. Time series of hourly-averaged data for instrument record WGM 22 (second half).

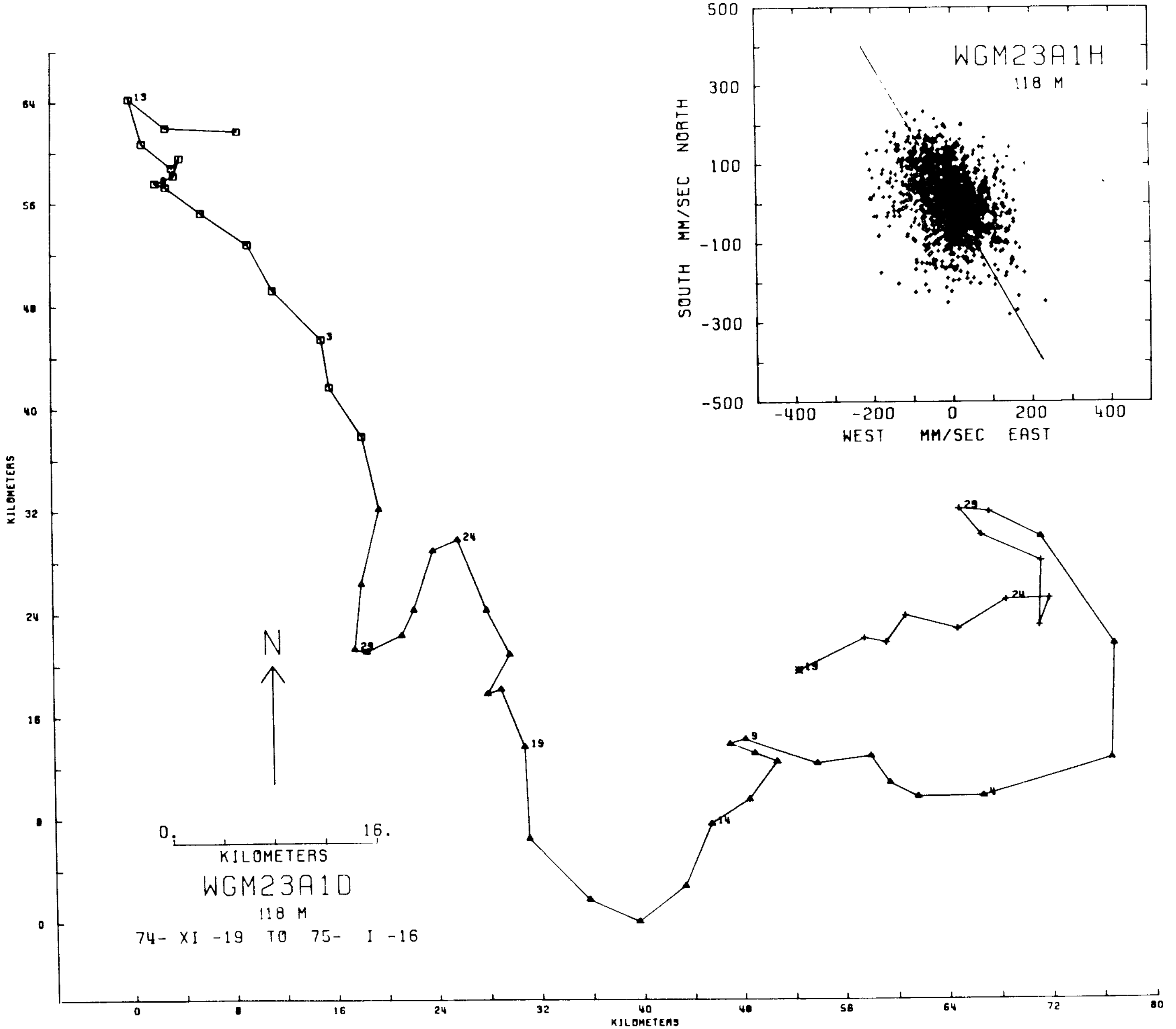


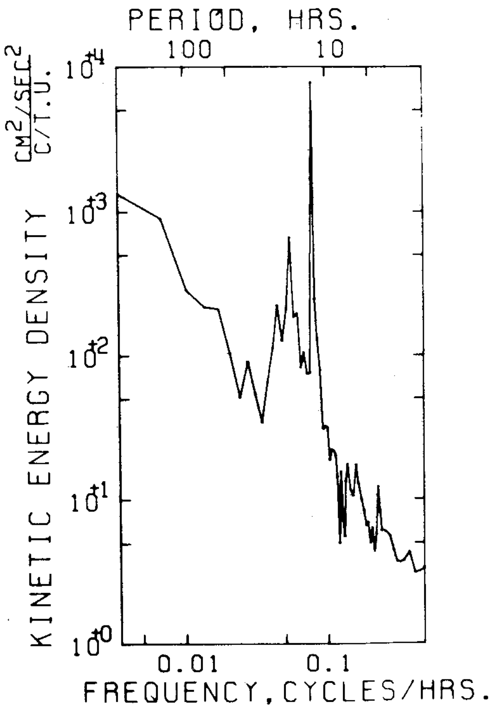
Figure 53. Progressive vector diagram of daily-averaged data and scatter plot of hourly-averaged data for instrument record WGM 23.

VARIABLE *	EAST COMP	NORTH COMP	SPEED
UNITS *	MM/SEC	MM/SEC	MM/SEC
MEAN =	-9.361	8.618	92.103
STD. ERR. =	1.799	2.225	1.440
VARIANCE =	4404.176	6737.416	2820.495
STD. DEV. =	66.364	82.082	53.108
KURTOSIS =	3.286	3.006	3.490
SKEWNESS =	-.436E-1	-.209	.765
MINIMUM =	-217.948	-280.049	.870
MAXIMUM =	232.699	231.188	339.700

EAST COMP & NORTH COMP	
COVARIANCE =	-1922.514
(U. ERR. OF COVARIANCE =	166.520
STD. DEV. OF COVARIANCE =	6143.199
CORRELATION COEFFICIENT =	-.353
VECTOR MEAN =	12.724
VECTOR VARIANCE =	5570.796
VECTOR STD. DEV. =	74.638

* SAMPLE SIZE = 1361 POINTS
*
* SPANNING RANGE
* FROM 74- XI -20 00.55.00
* TO 75- I -15 16.55.00
*
* DURATION 56.67 DAYS

AUTO SPECTRUM
WGM23A1H EAST COMP
WGM23A1H NORTH COMP
118 METERS
74-XI-20 TO 75-I-18
1 PIECES WITH 720 ESTIMATES
PER PIECE. AVERAGED OVER
5 ADJACENT FREQUENCY BANDS
07:15 MAR 08.'77



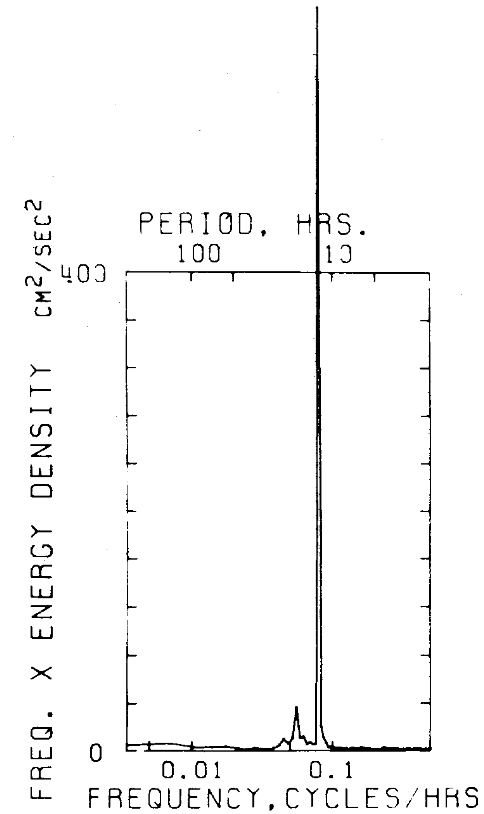


Figure 54. Statistics and spectra computed from hourly-averaged data for instrument record WGM 23.

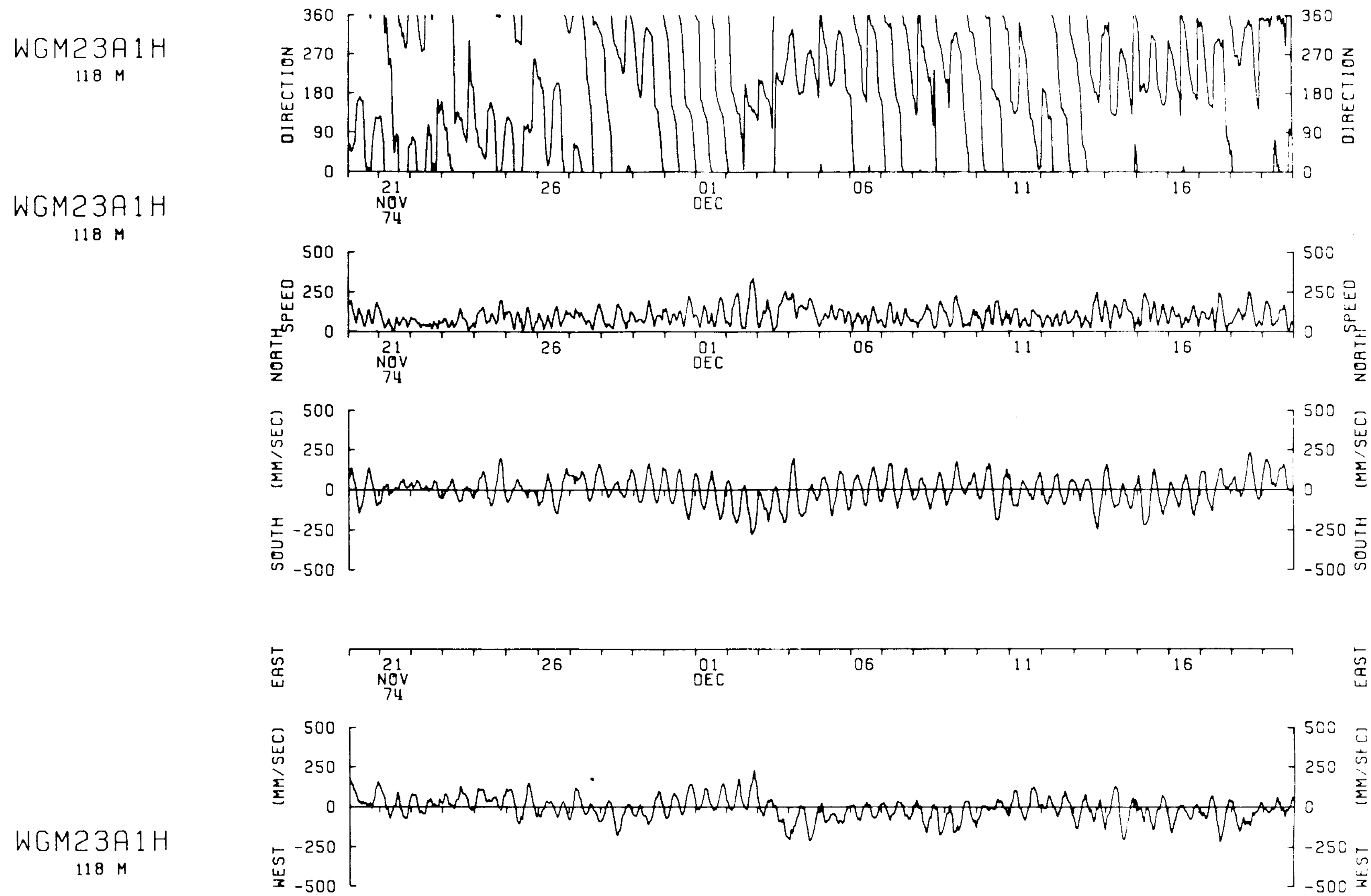


Figure 55. Time series of hourly-averaged data for instrument record WGM 23 (first half).

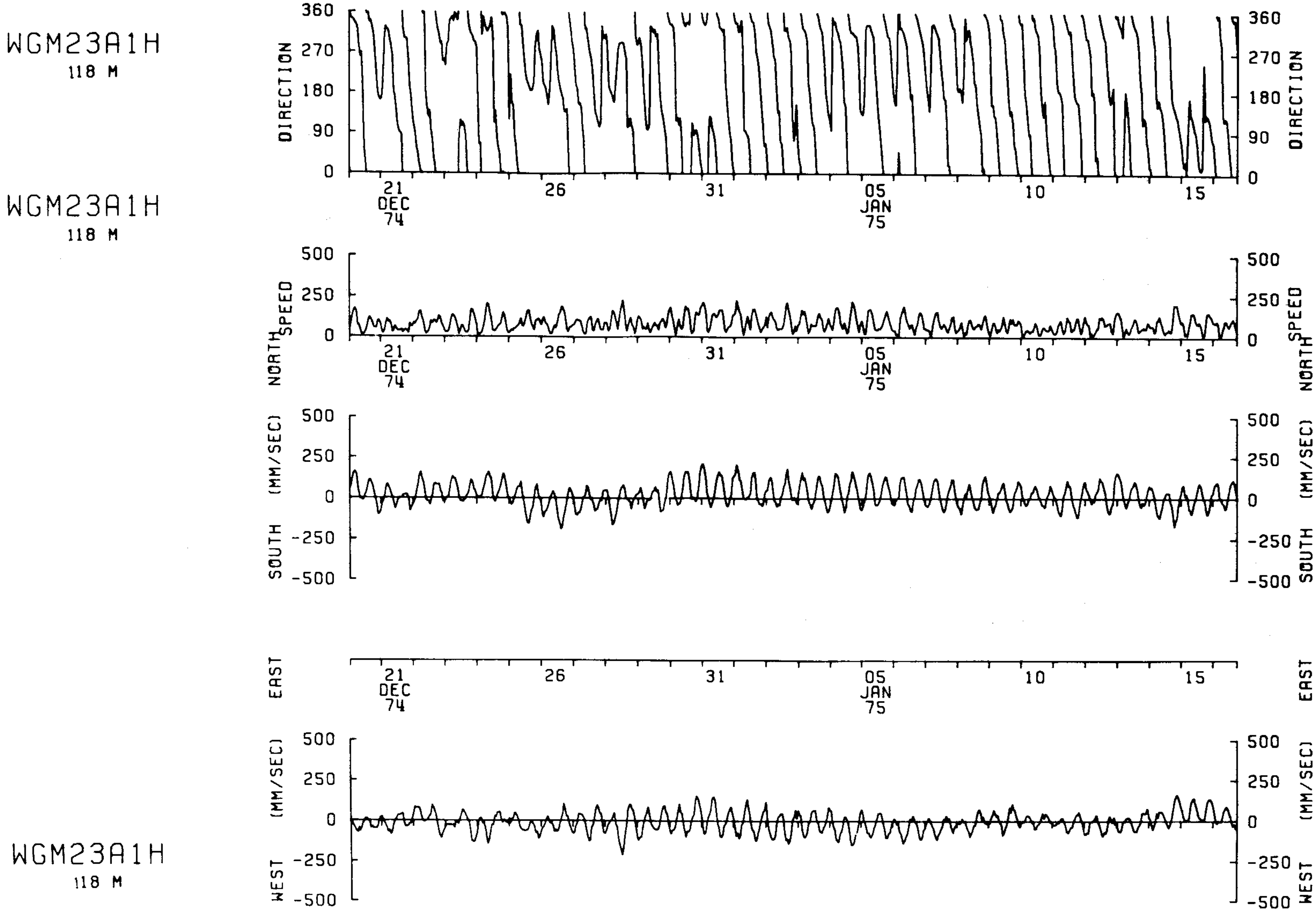


Figure 56. Time series of hourly-averaged data for instrument record WGM 23 (second half).

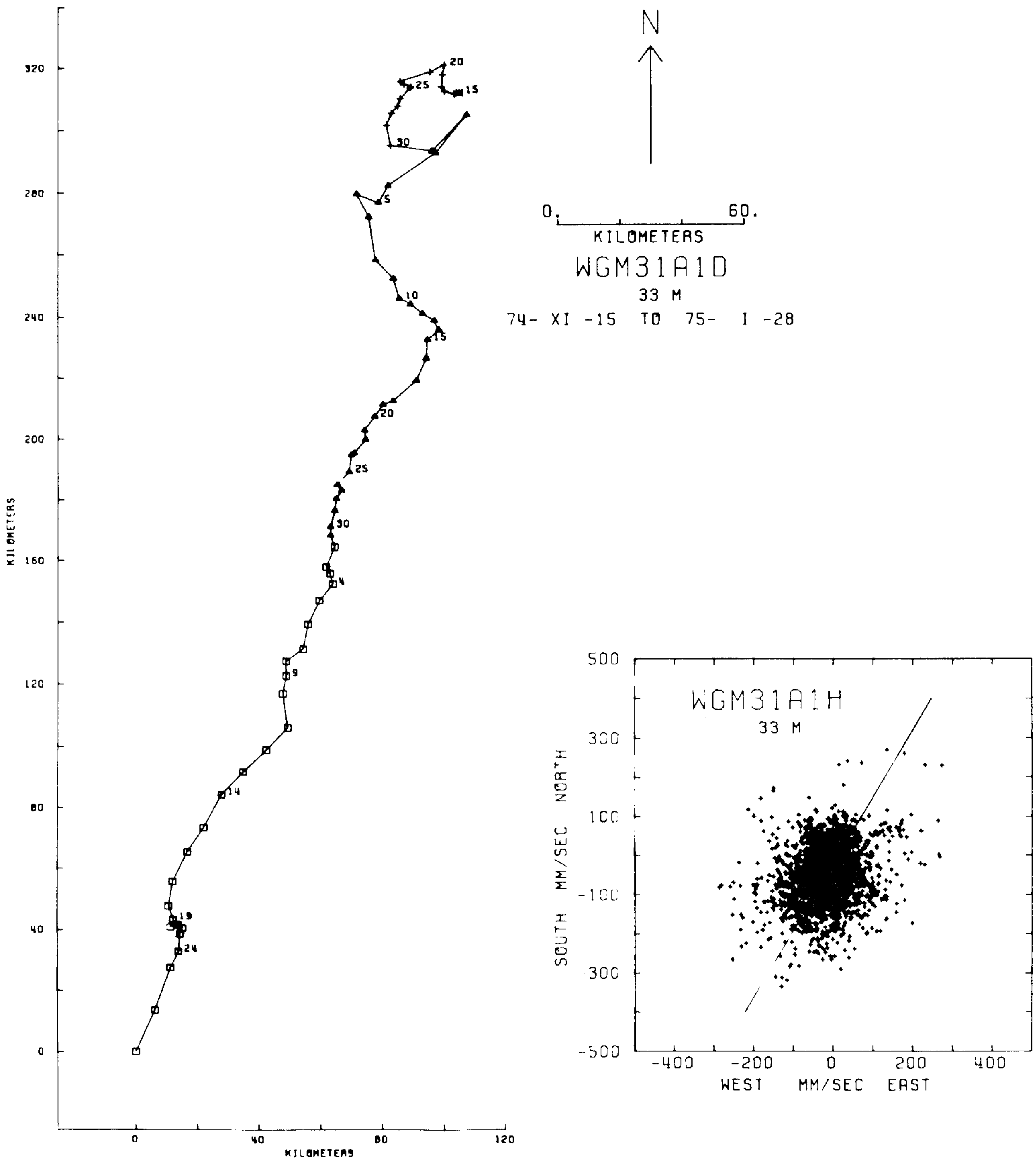


Figure 57. Progressive vector diagram of daily-averaged data and scatter plot of hourly-averaged data for instrument record WGM 31.

VARIABLE	EAST	NORTH	SPEED	TEMPERATURE
UNITS	MM/S	MM/S	MM/S	DEGREES C.
MEAN	-15.641	-49.581	103.391	7.111
STD. ERR.	2.030	2.094	1.624	.221E-1
VARIANCE	5607.144	5966.959	3587.389	.664
STD. DEV.	74.881	77.246	59.895	.815
KURTOSIS	4.272	3.931	4.792	3.125
SKEWNESS	.347E-1	.115	1.221	.832
MINIMUM	-286.115	-334.584	4.163	5.776
MAXIMUM	273.434	270.057	366.649	9.281

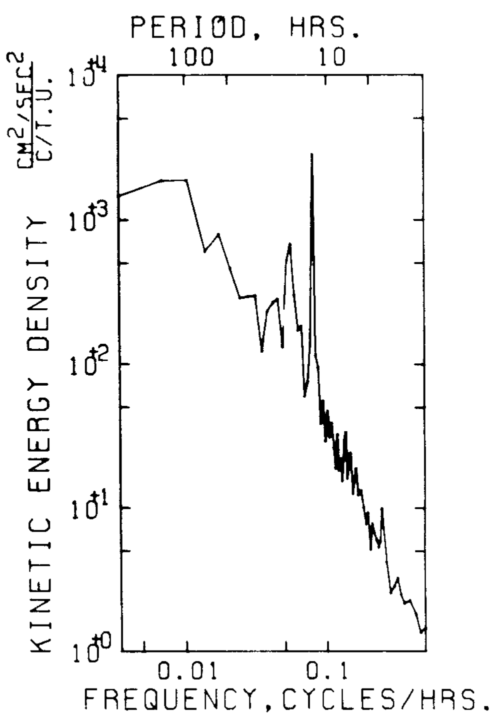
EAST & NORTH	
COVARIANCE	1191.888
STD. ERR. OF COVARIANCE	228.055
STD. DEV. OF COVARIANCE	8413.361
CORRELATION COEFFICIENT	.206
VECTOR MEAN	51.990
VECTOR VARIANCE	5787.051
VECTOR STD. DEV.	76.073

SAMPLE SIZE = 1361 POINTS

SPANNING RANGE
FROM 74- XI -20 01.07.30
TO 75- I -15 17.07.30

DURATION 56.67 DAYS

AUTO SPECTRUM
WGM31A1H EAST
WGM31A1H NORTH
33 METERS
74-XI-20 TO 75-I-19
1 PIECES WITH 720 ESTIMATES
PER PIECE. AVERAGED OVER
5 ADJACENT FREQUENCY BANDS
14:08 MAR 07,'77



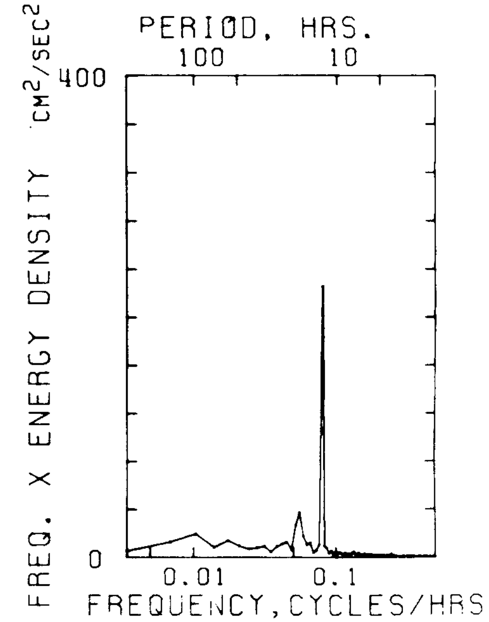


Figure 58. Statistics and spectra computed from hourly-averaged data for instrument record WGM 31.

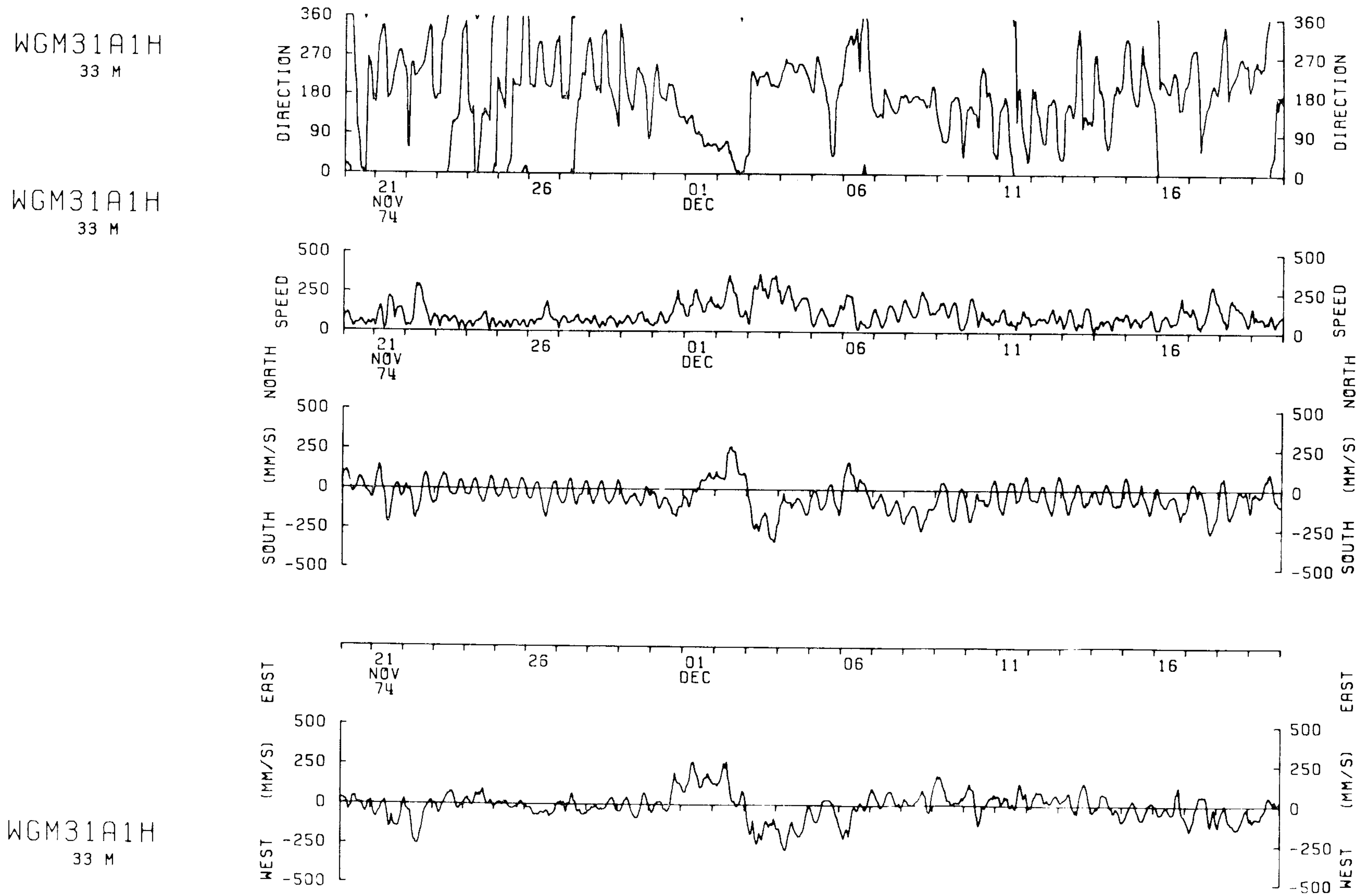


Figure 59. Time series of hourly-averaged data for instrument record WGM 31 (first half).

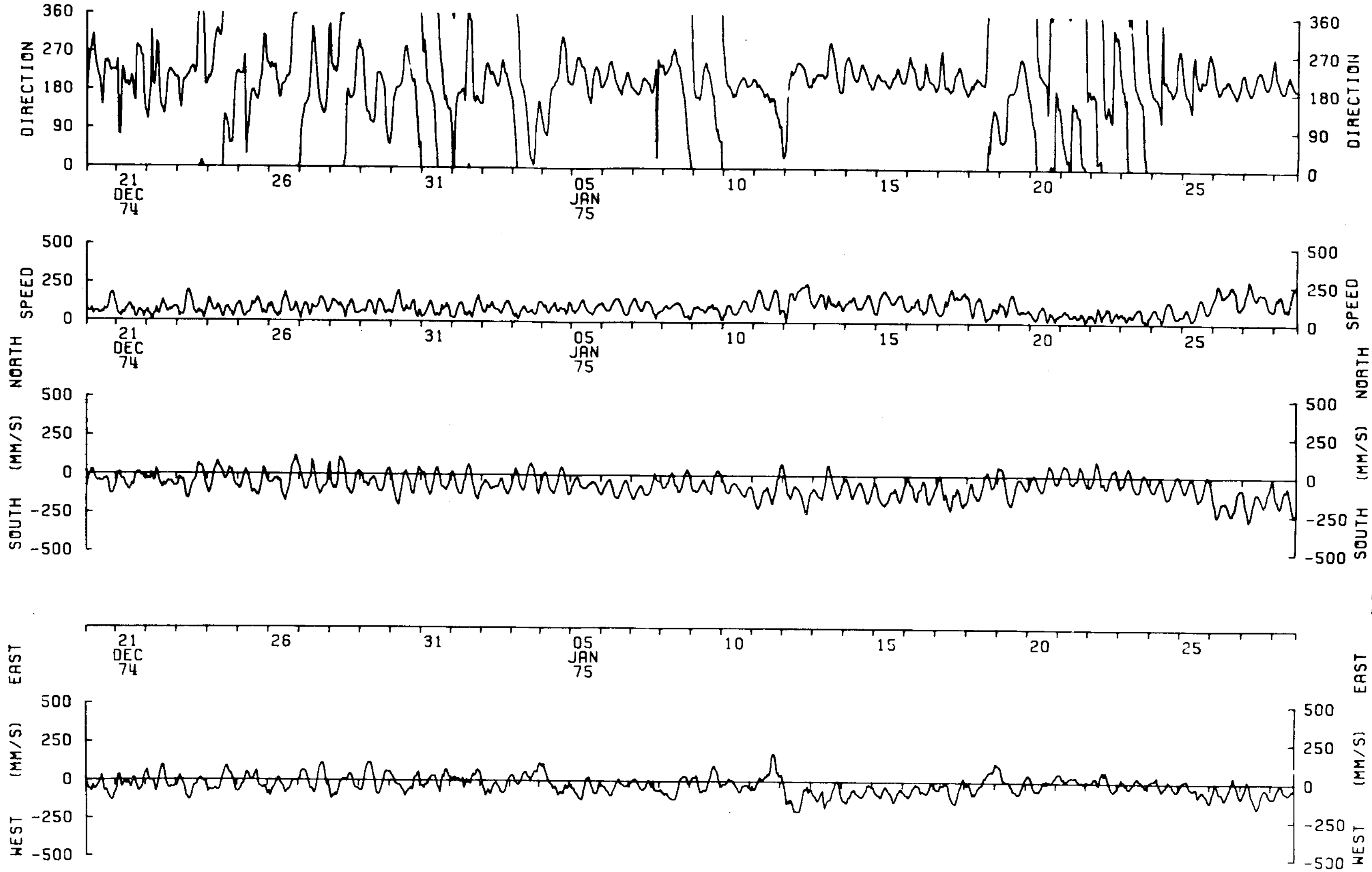


Figure 60. Time series of hourly-averaged data for instrument record WGM 31 (second half).

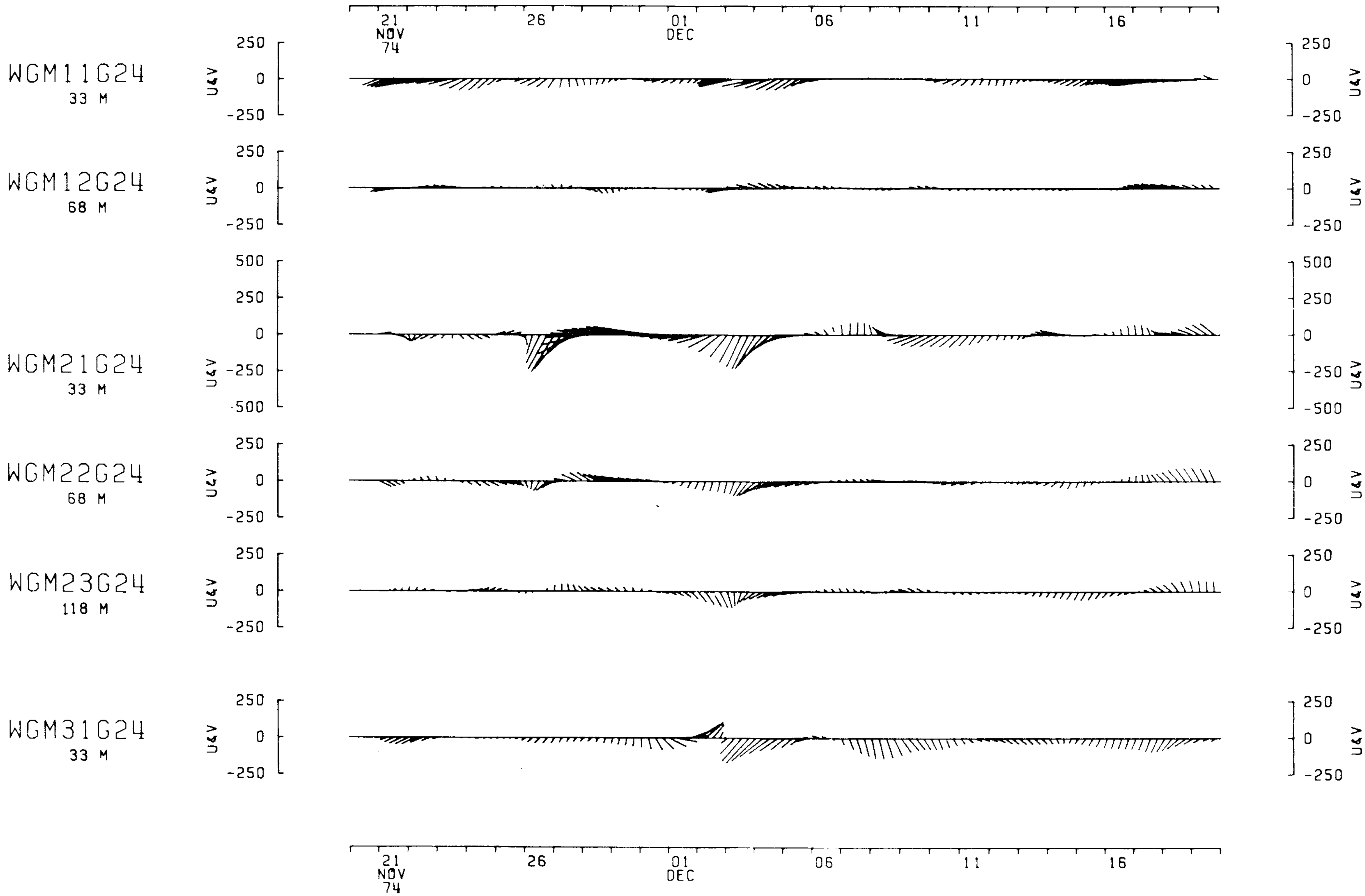


Figure 61. Vector plot of Western Gulf of Maine currents (first half). Low-passed by applying running Gaussian filter with T_{half} = 24 hours.

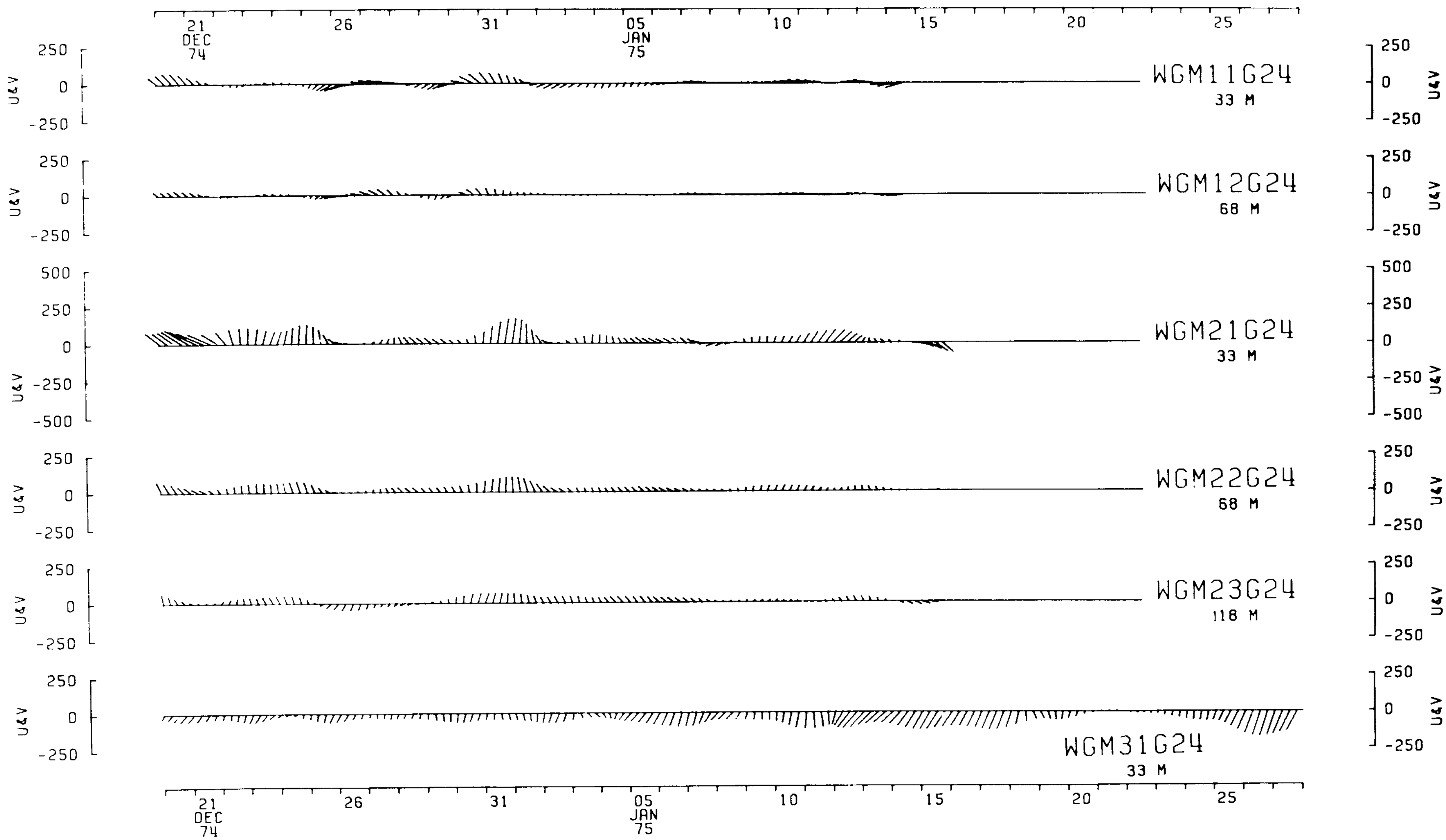


Figure 62. Vector plot of Western Gulf of Maine currents (second half). Low-passed by applying running Gaussian filter with $T_{half} = 24$ hours.

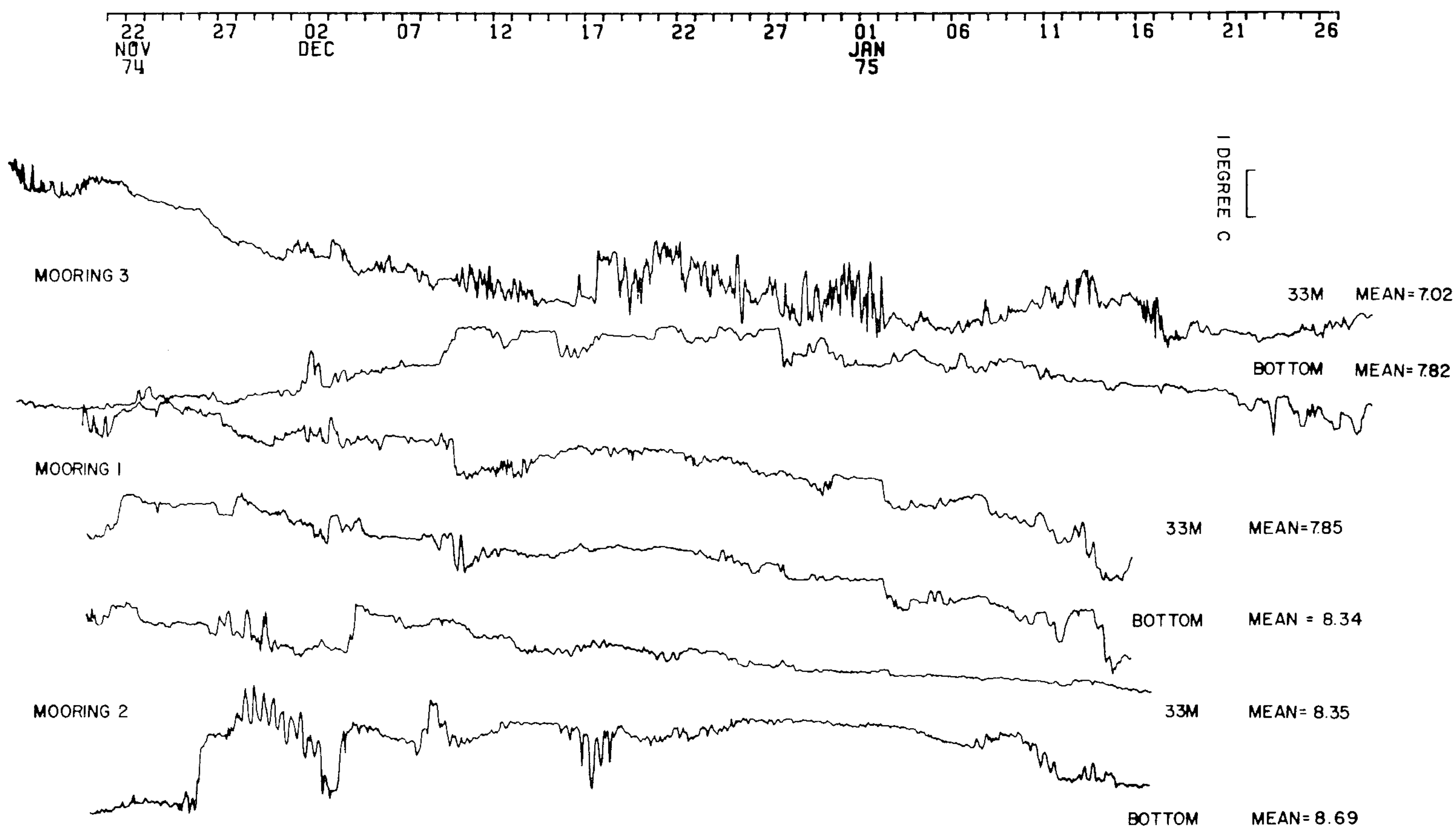


Figure 63. Moored temperatures from Western Gulf of Maine experiment.

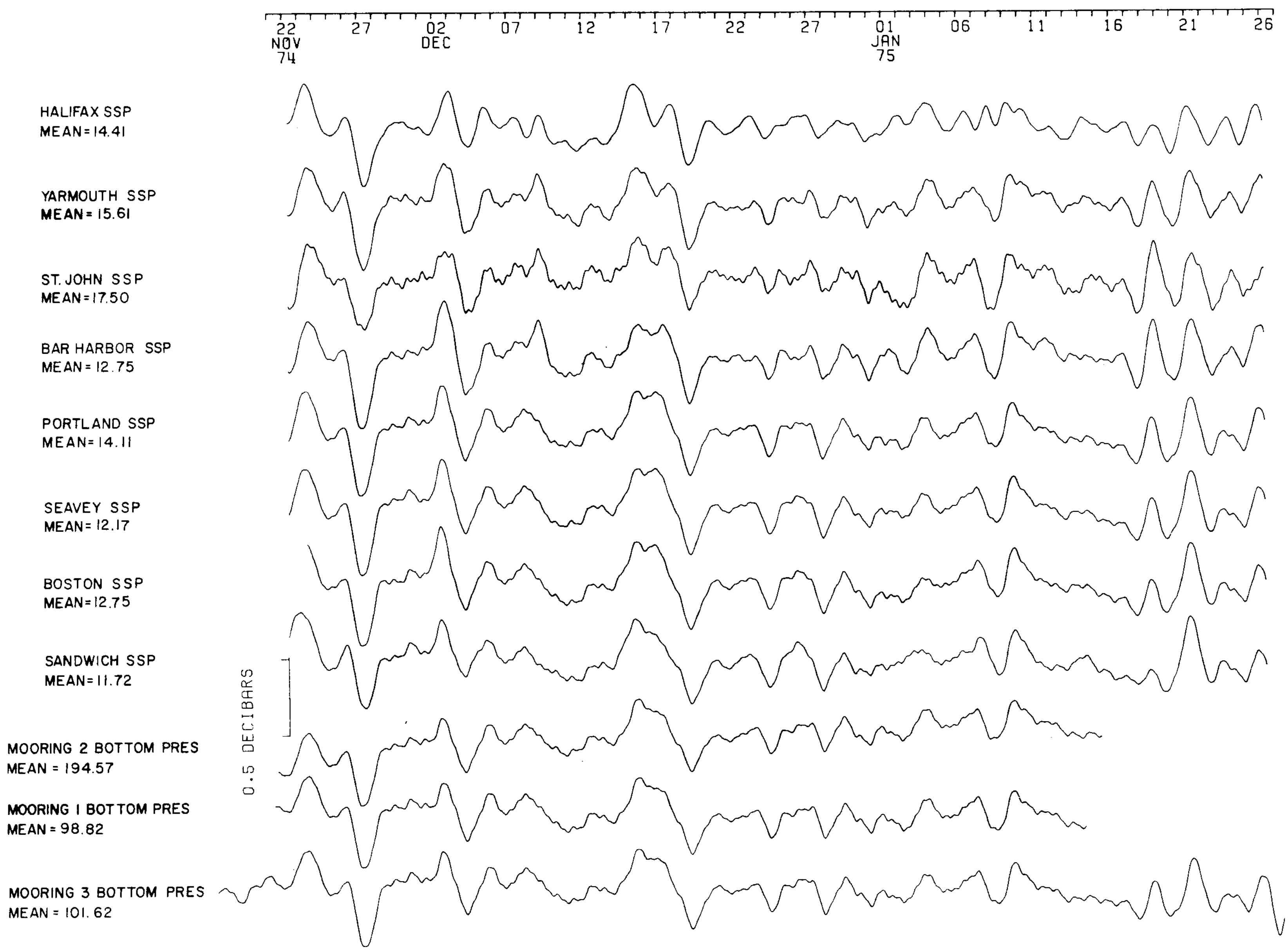


Figure 64. Coastal sub-surface pressure (SSP) and moored bottom pressures from Western Gulf of Maine experiment. Low-passed by applying PL33 filter.

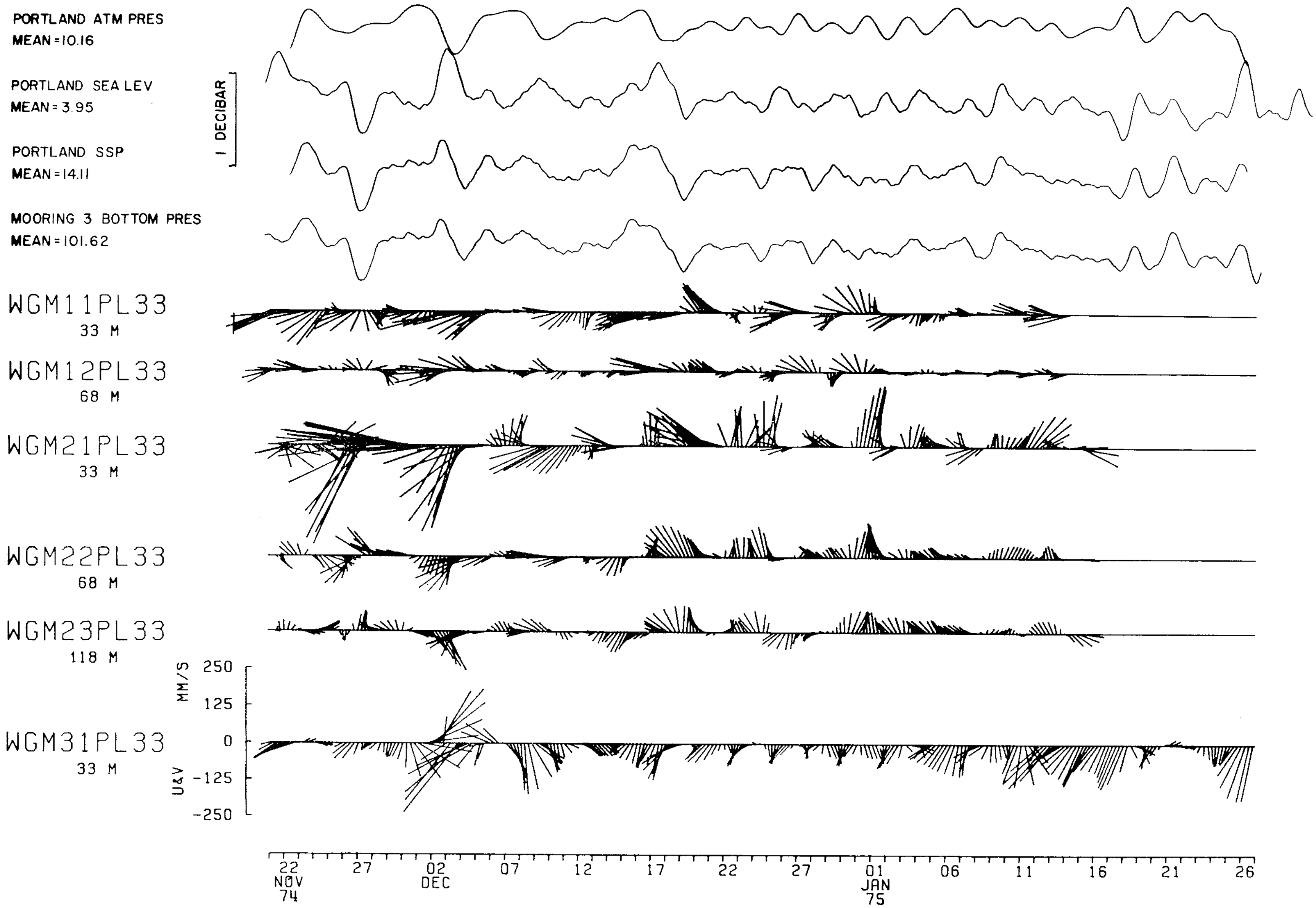


Figure 65. Western Gulf of Maine selected pressure data and vector plot of all currents. Low-passed by applying PL33 filter.

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4. Title and Subtitle

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5. Report Date
June 1977

6.

7. Author(s)
W. S. Brown, J. A. Vermersch, and R. C. Beardsley

8. Performing Organization Rept. No. WHOI-77-22

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Woods Hole Oceanographic Institution
Woods Hole, MA 02543

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15. Supplementary Notes

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2. Hydrographic Data
3. Moored Array Data

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 89
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